US010030655B2

(12) **United States Patent**
Terada

(10) **Patent No.: US 10,030,655 B2**
(45) **Date of Patent: Jul. 24, 2018**

(54) **OIL PUMP**

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(72) Inventor: **Mitsuru Terada**, Okazaki (JP)

(73) Assignee: **AISIN SEIKI KABUSHIKI KAISHA**, Kariya-shi, Aichi-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 168 days.

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(22) PCT Filed: **Sep. 1, 2014**

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(2) Date: **Mar. 4, 2016**

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PCT Pub. Date: **Apr. 2, 2015**

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(30) **Foreign Application Priority Data**

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Oct. 30, 2013 (JP) 2013-224862

(51) **Int. Cl.**
F04C 14/22 (2006.01)
F04C 2/34 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F04C 14/223*** (2013.01); ***F04C 2/332*** (2013.01); ***F04C 2/3448*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC F04C 13/001; F04C 14/223; F04C 15/06; F04C 2/332; F04C 2/3448; F04C 2210/206
(Continued)

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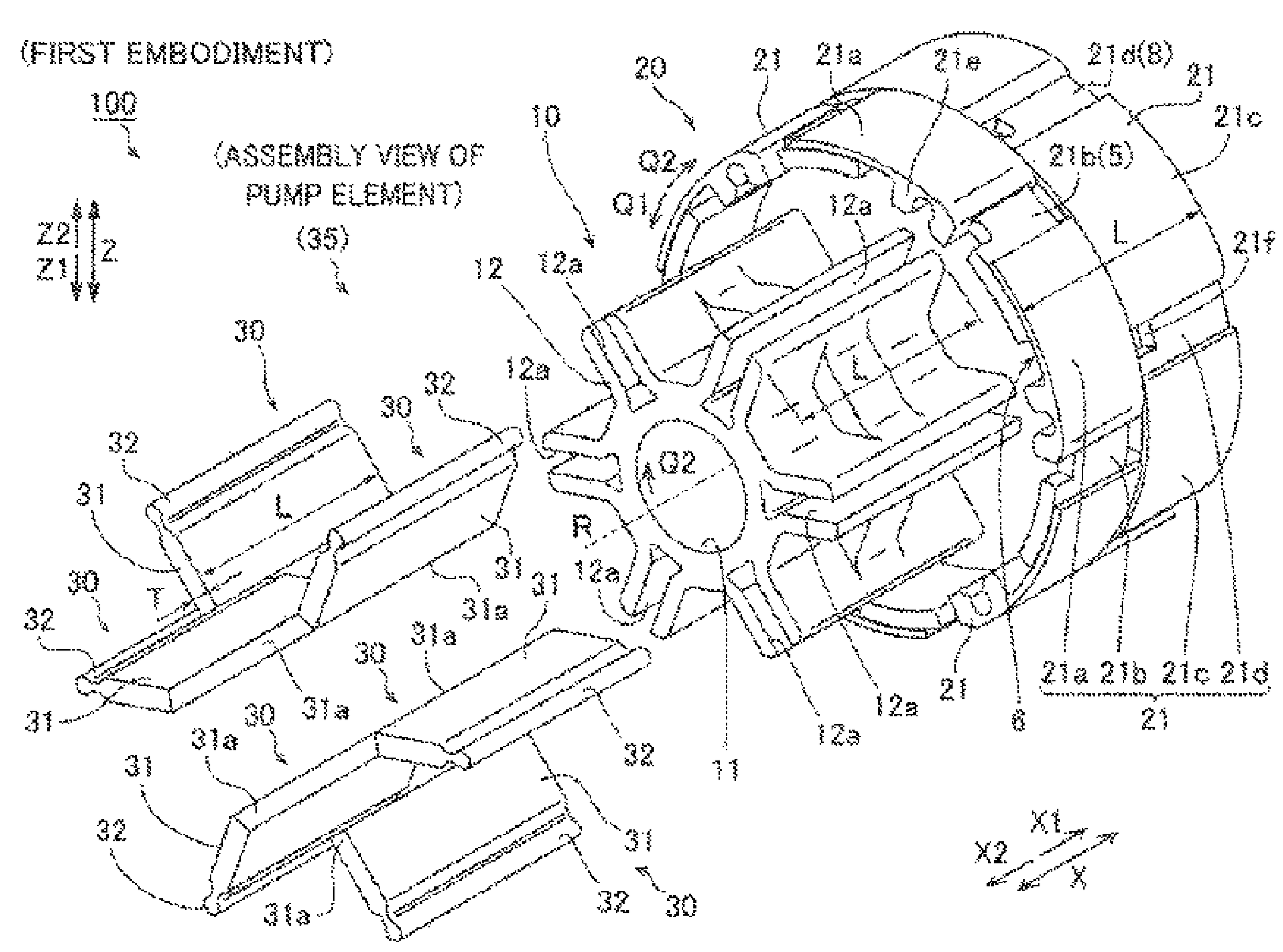
Primary Examiner — Mary A Davis
Assistant Examiner — Dapinder Singh
(74) *Attorney, Agent, or Firm* — Buchanan Ingersoll & Rooney PC

(57) **ABSTRACT**

This oil pump is equipped with a rotatable inner rotor that includes a vane-housing unit housing multiple vanes so as to be capable of sliding in the radial direction, a rotatable annular outer rotor that includes multiple vane-connecting parts connecting the tip ends of the multiple vanes on the outside in the radial direction, first volume-changing parts, which are provided between the inner rotor and the outer rotor, and a first volume of which is changed in response to eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function, and second volume-changing parts, which are provided in the outer rotor, and a second volume of which is changed by a change in the distance between adjacent vane-connecting parts in the circumferential direction in response to eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function.

14 Claims, 14 Drawing Sheets



(51) **Int. Cl.**

F04C 13/00	(2006.01)
F04C 15/00	(2006.01)
F04C 2/344	(2006.01)
F04C 15/06	(2006.01)
F04C 2/332	(2006.01)

(52) **U.S. Cl.**
CPC ***F04C 13/001*** (2013.01); ***F04C 15/06*** (2013.01); *F04C 2210/206* (2013.01)

(58) **Field of Classification Search**
USPC 418/5, 23, 24, 26, 173
See application file for complete search history.

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FIG.1

(FIRST EMBODIMENT)

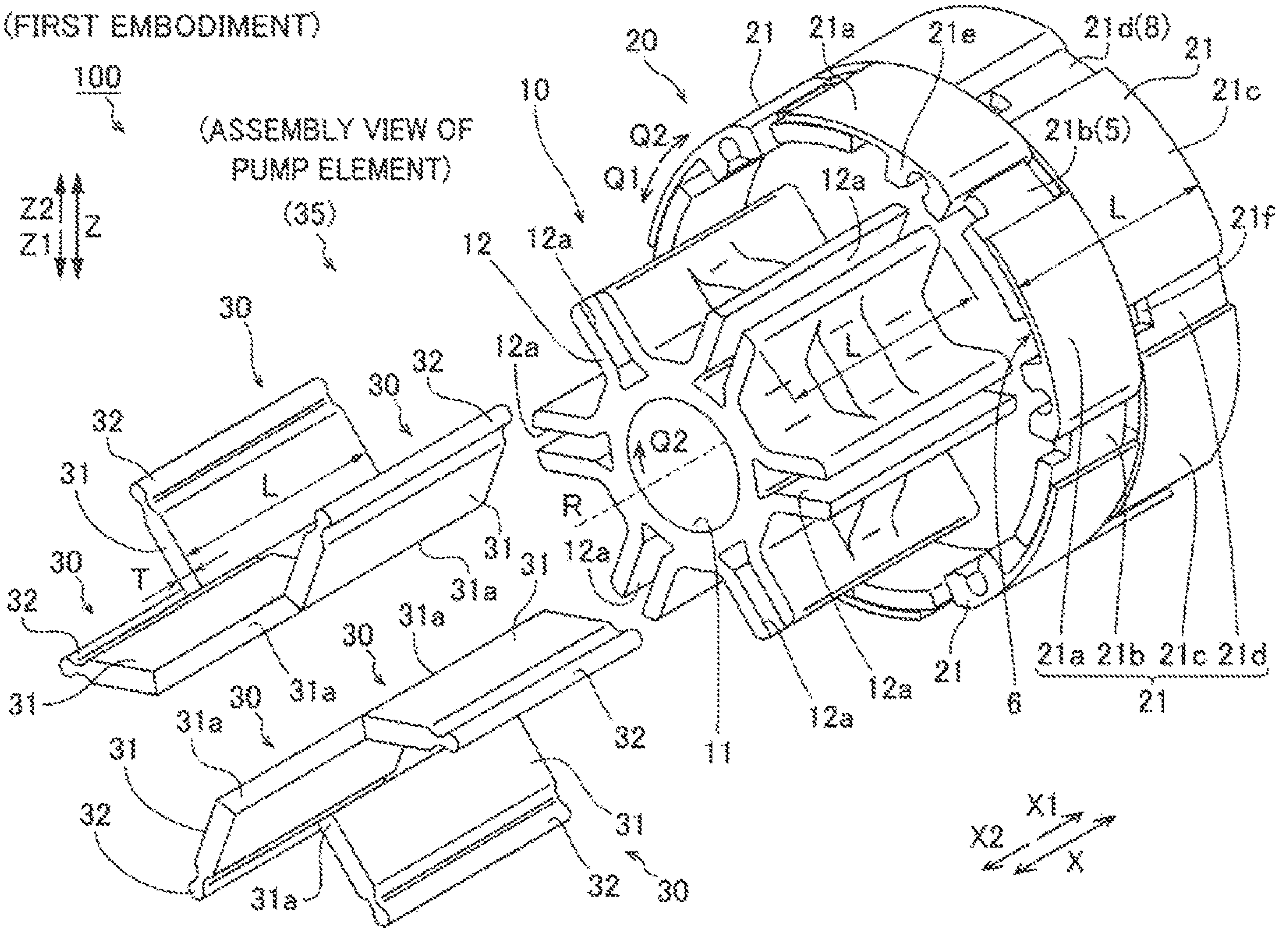


FIG.2

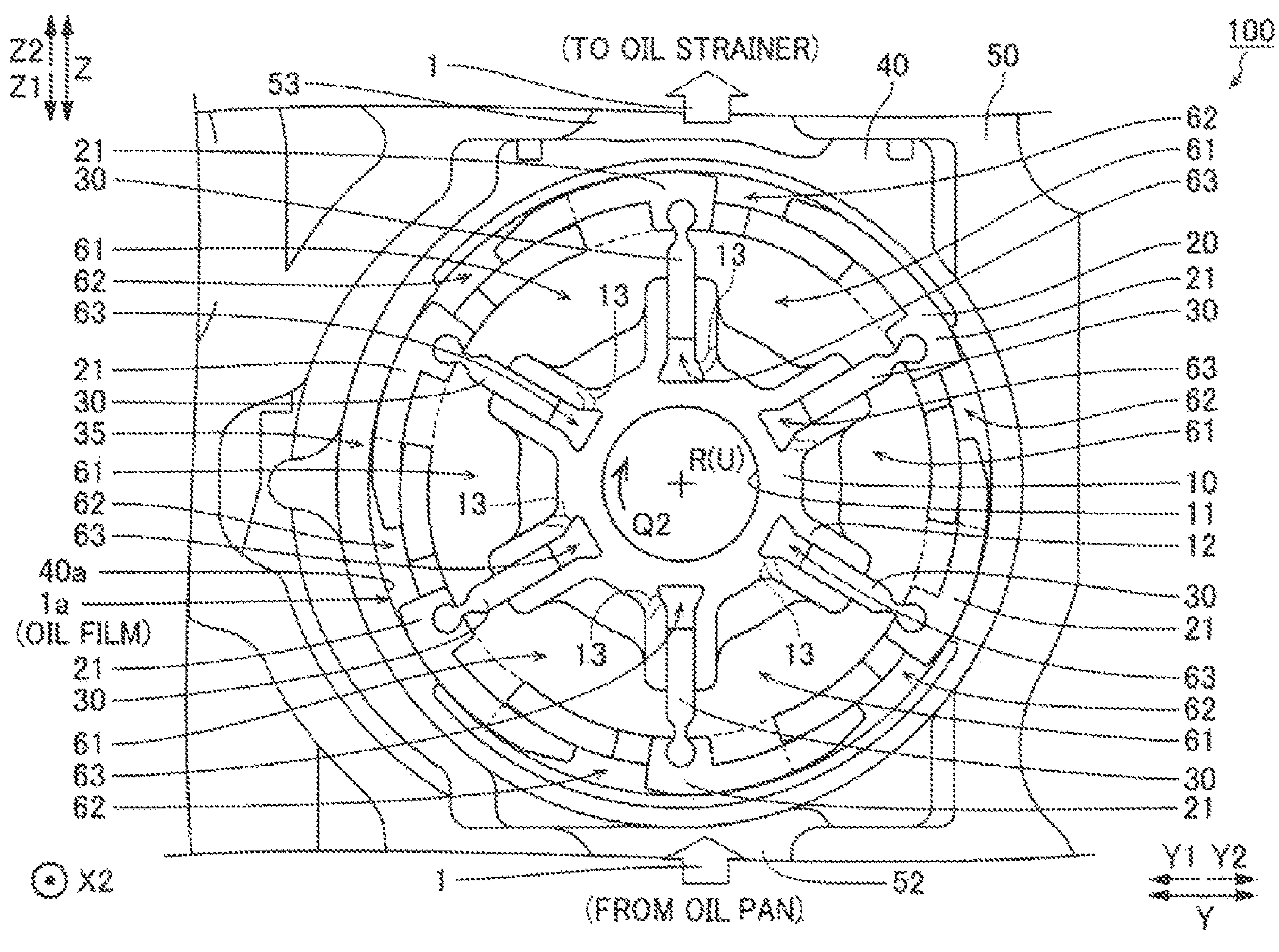


FIG.3

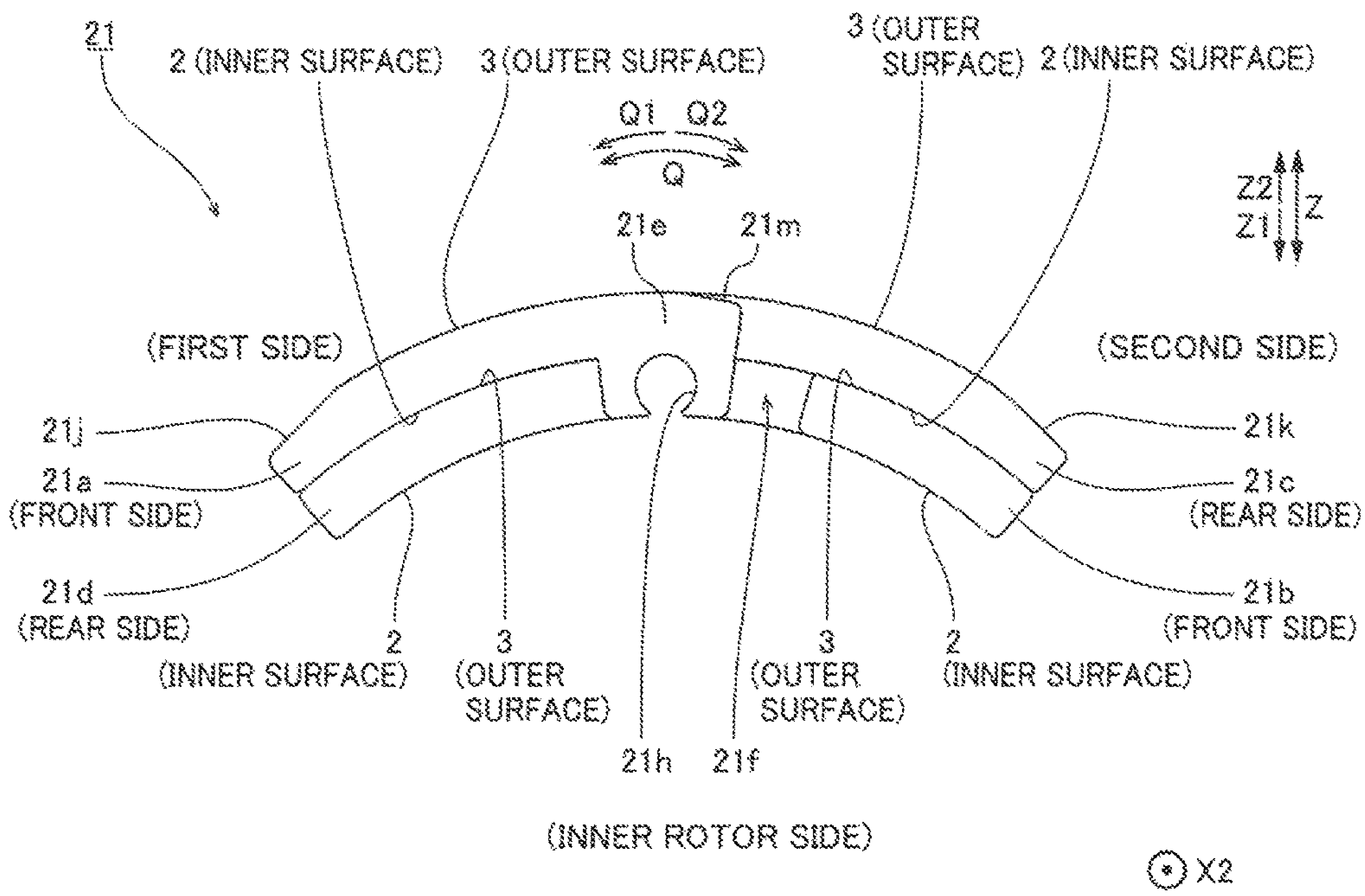

21
2 (INNER SURFACE)
3 (OUTER SURFACE)
3 (OUTER SURFACE)
2 (INNER SURFACE)
Q1 Q2
Q
Z2
Z1
Z
21e
21m
(FIRST SIDE)
(SECOND SIDE)
21j
21a (FRONT SIDE)
21d (REAR SIDE)
21k
21c (REAR SIDE)
21b (FRONT SIDE)
2 (INNER SURFACE)
3 (OUTER SURFACE)
3 (OUTER SURFACE)
2 (INNER SURFACE)
21h
21f
(INNER ROTOR SIDE)
X2

FIG.4

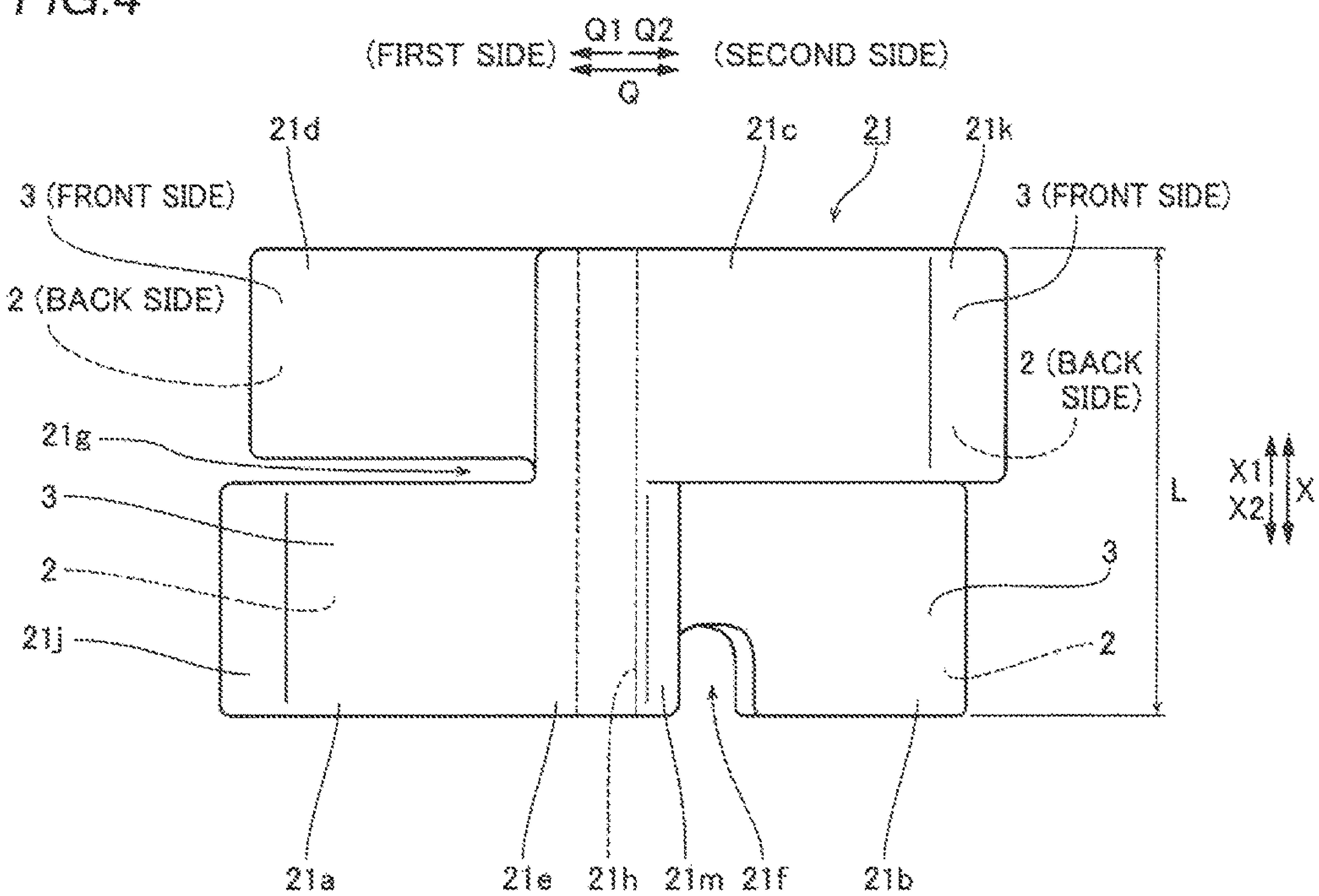

(FIRST SIDE)
Q1 Q2
Q
(SECOND SIDE)
21d
21c
21
21k
3 (FRONT SIDE)
2 (BACK SIDE)
3 (FRONT SIDE)
2 (BACK SIDE)
21g
3
2
21j
L
X1
X2
X
3
2
21a
21e
21h
21m
21f
21b

FIG.5

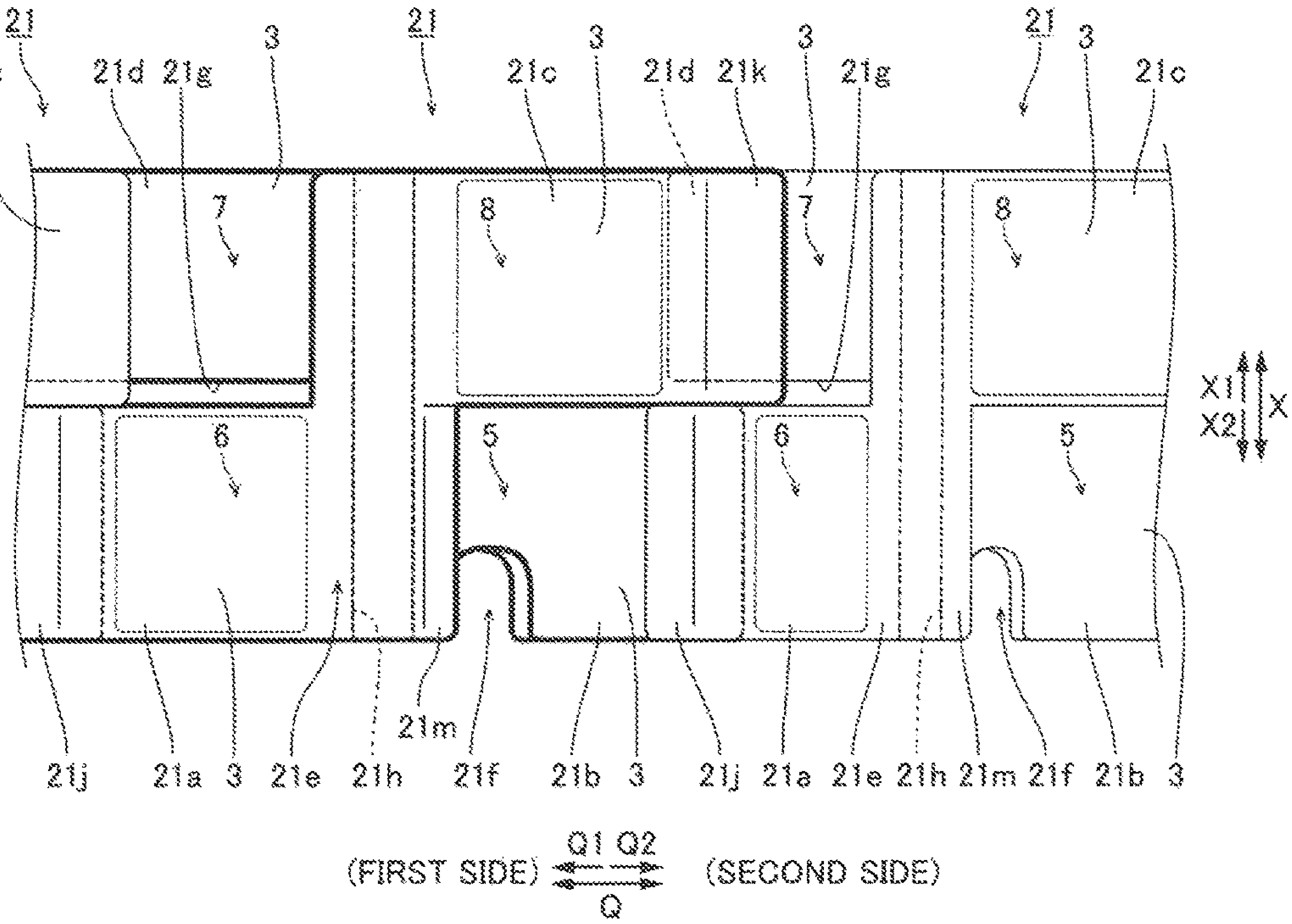

21
21c
21d
21g
3
7
8
21k
X1
X2
X
6
5
21j
21a
21e
21h
21m
21f
21b
(FIRST SIDE)
Q1 Q2
Q
(SECOND SIDE)

FIG.6

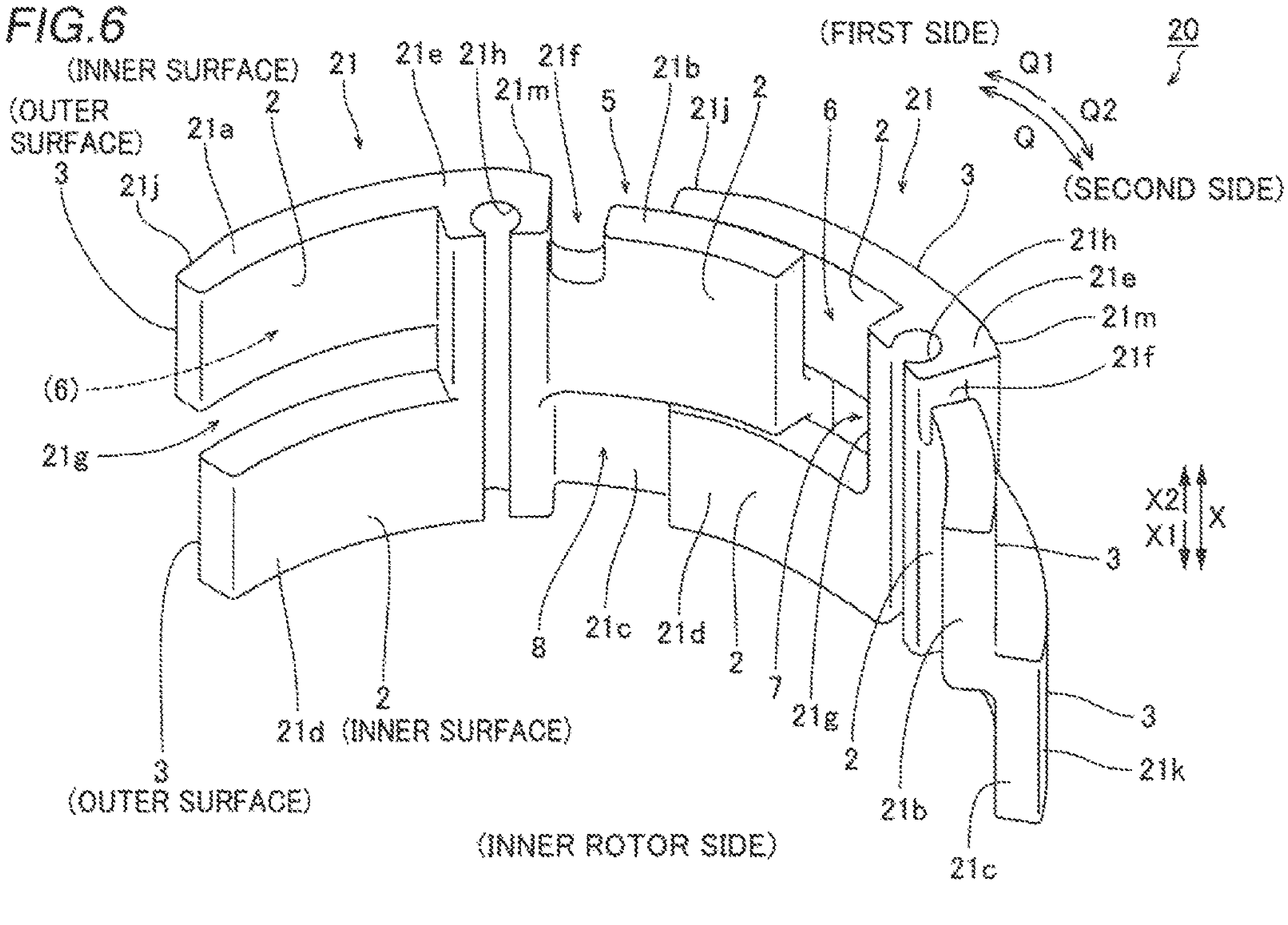

(INNER SURFACE)
(OUTER SURFACE)
(FIRST SIDE)
20
Q1
Q2
Q
(SECOND SIDE)
21
21a
21e
21h
21f
21b
21m
21j
5
6
2
3
(6)
21g
X2
X1
X
8
21c
21d
7
21k
2 (INNER SURFACE)
3 (OUTER SURFACE)
(INNER ROTOR SIDE)

FIG.7

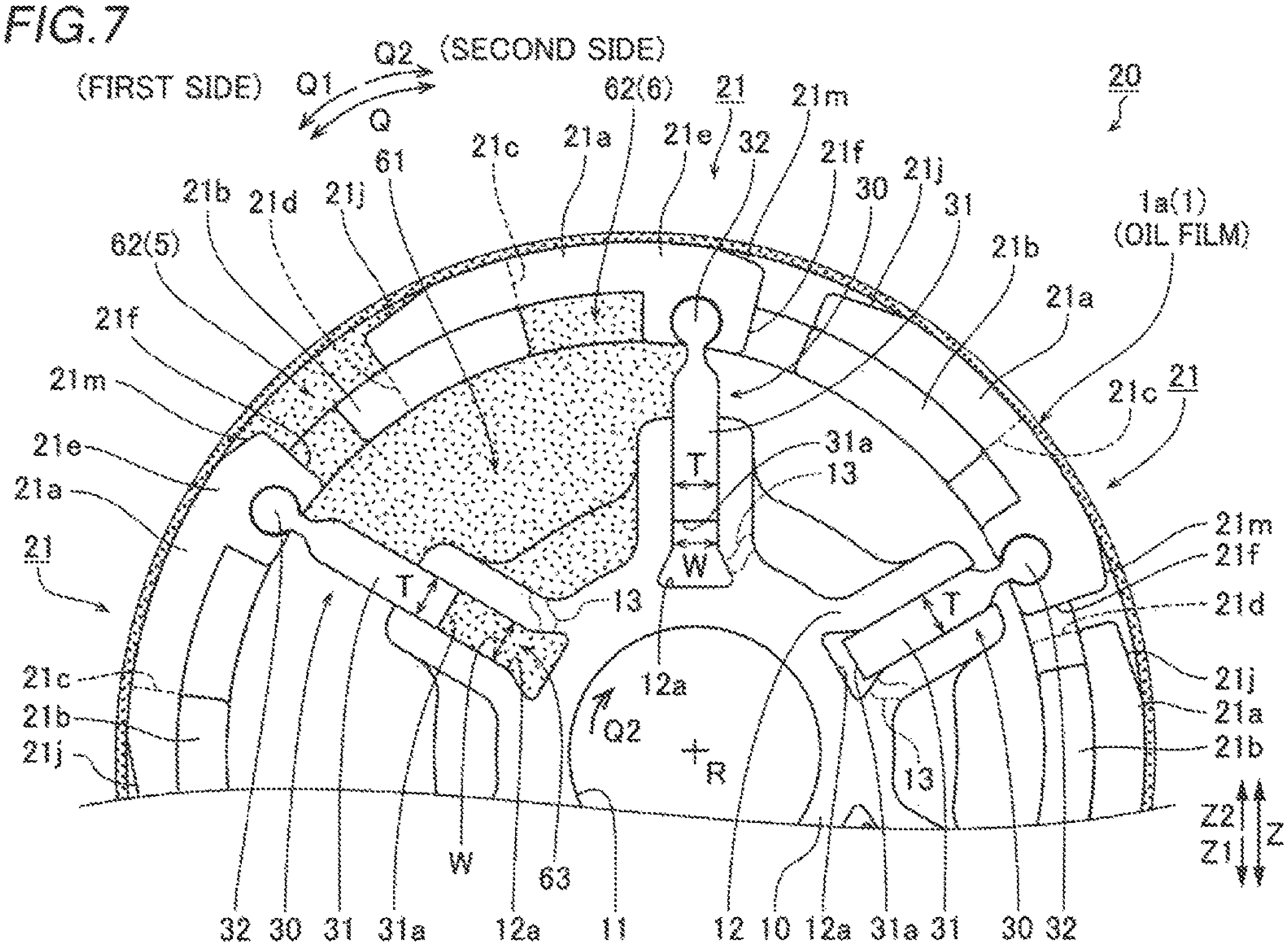

Q2 (SECOND SIDE)
(FIRST SIDE) Q1
Q
62(6)
21
21m
20
1a(1)
(OIL FILM)
12a
Q2
R
Z2
Z1
Z
W
T

FIG.8

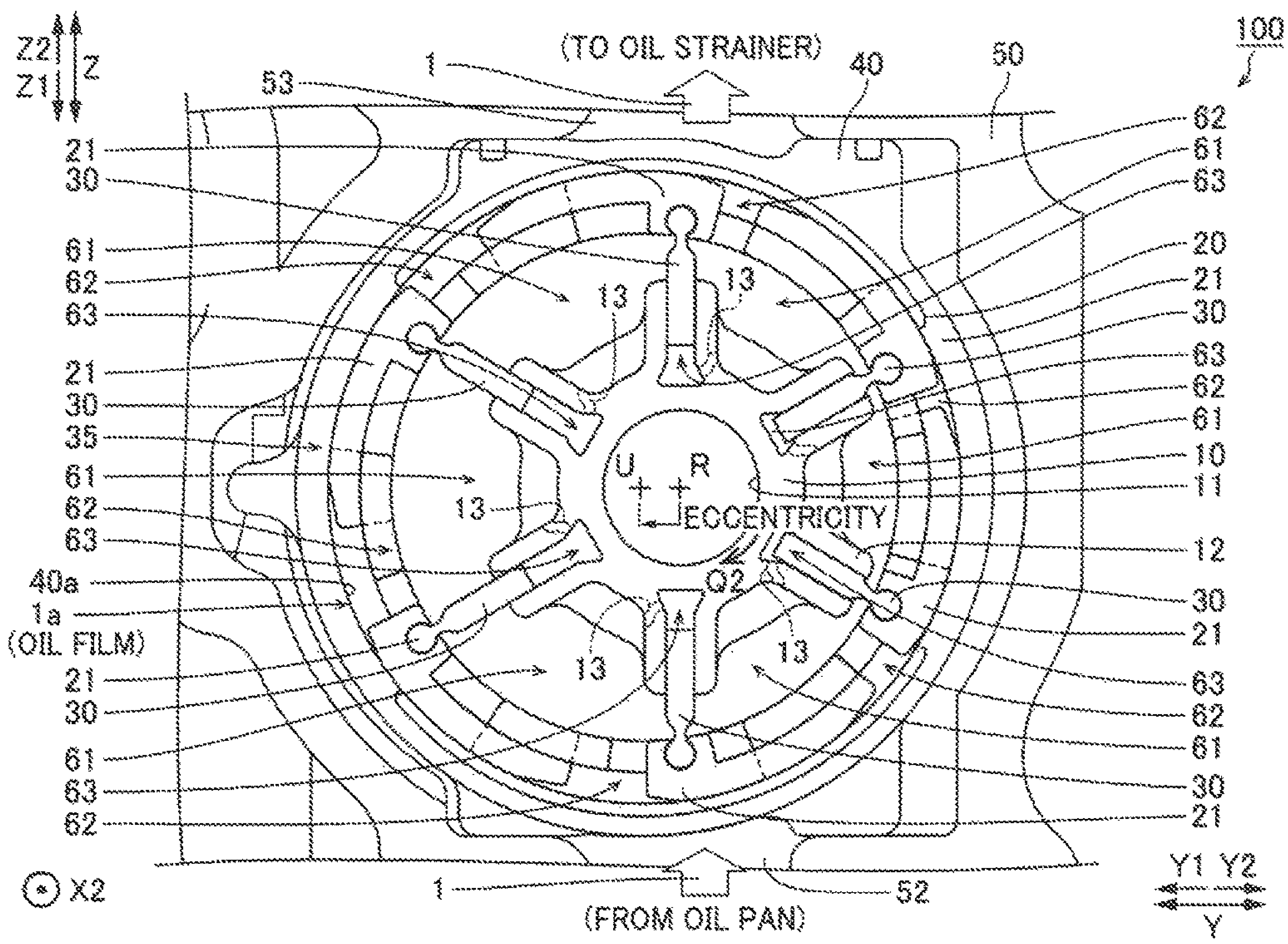

(TO OIL STRAINER)
100
U
R
ECCENTRICITY
Q2
1a
(OIL FILM)
X2
(FROM OIL PAN)
Y1 Y2
Y
Z2
Z1
Z

FIG.9

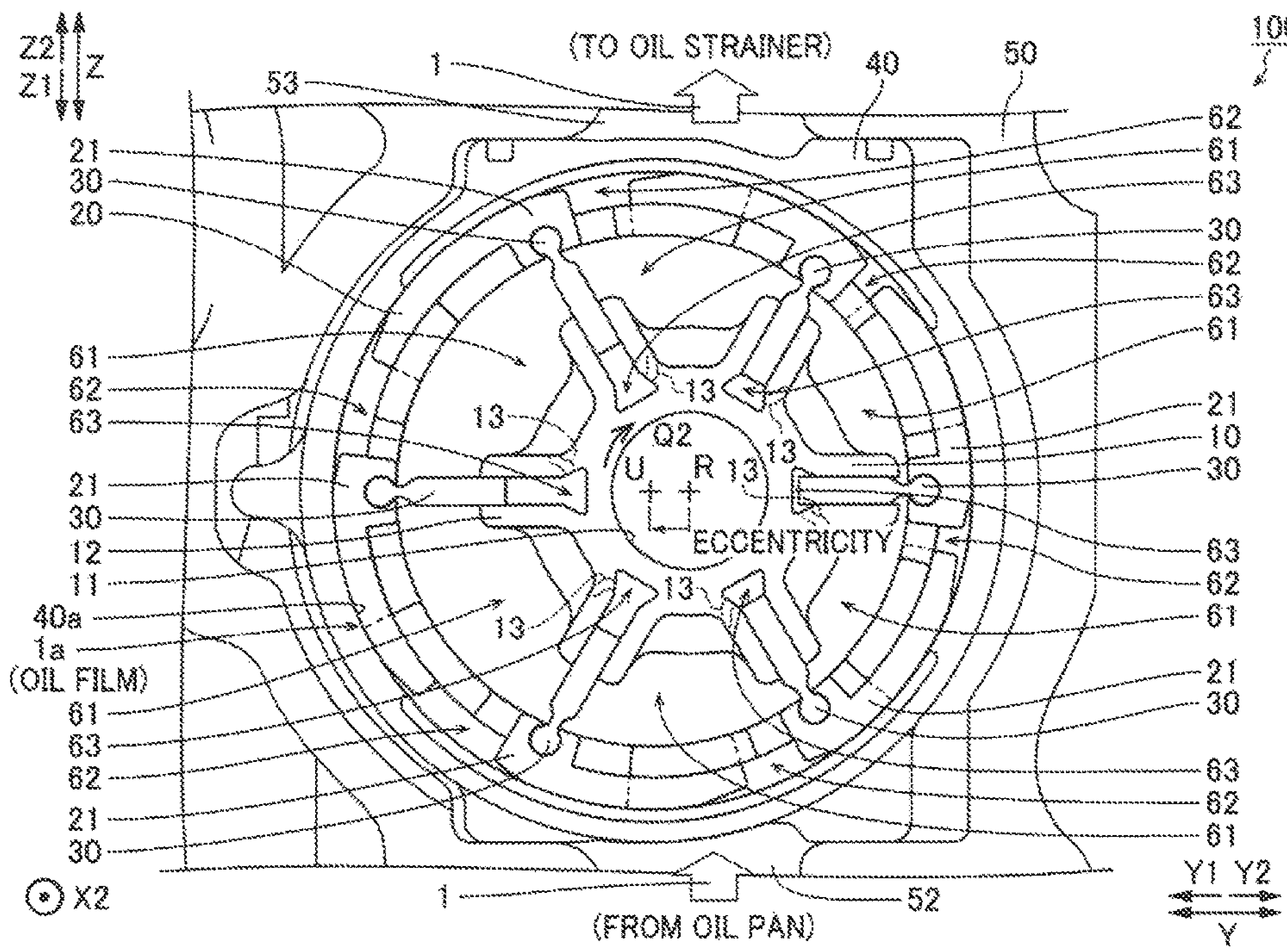

100
(TO OIL STRAINER)
(FROM OIL PAN)
(OIL FILM)
ECCENTRICITY
Q2
U
R
X2
Z2
Z1
Z
Y1 Y2
Y
53
1
40
50
62
61
63
30
21
20
13
10
12
11
40a
1a
52

FIG.10

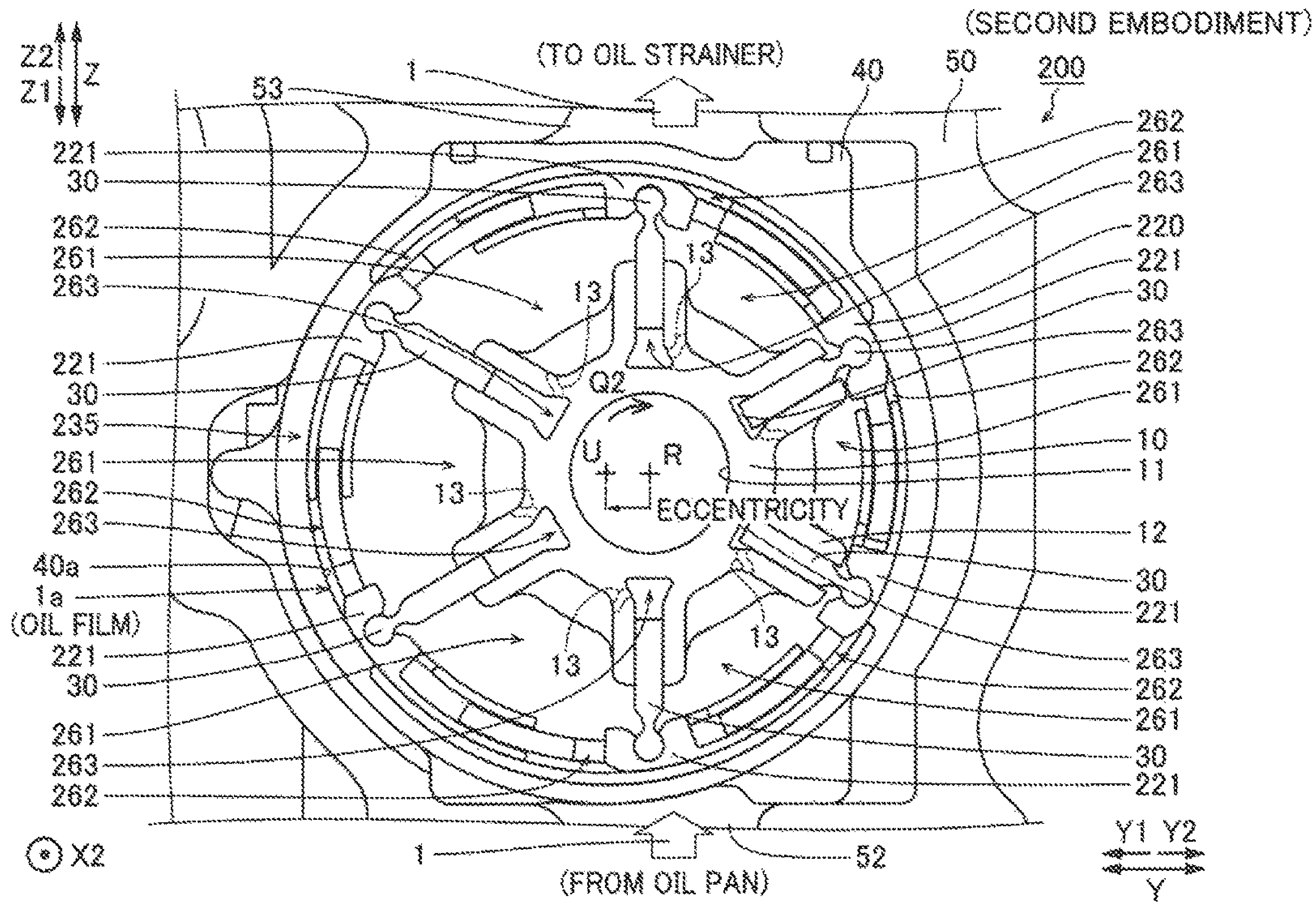

(SECOND EMBODIMENT)
200
(TO OIL STRAINER)
(FROM OIL PAN)
(OIL FILM)
ECCENTRICITY
Q2
U
R
X2
Z2
Z1
Z
Y1 Y2
Y
53
1
40
50
262
261
263
221
220
30
235
13
10
11
12
40a
1a
52

FIG.11

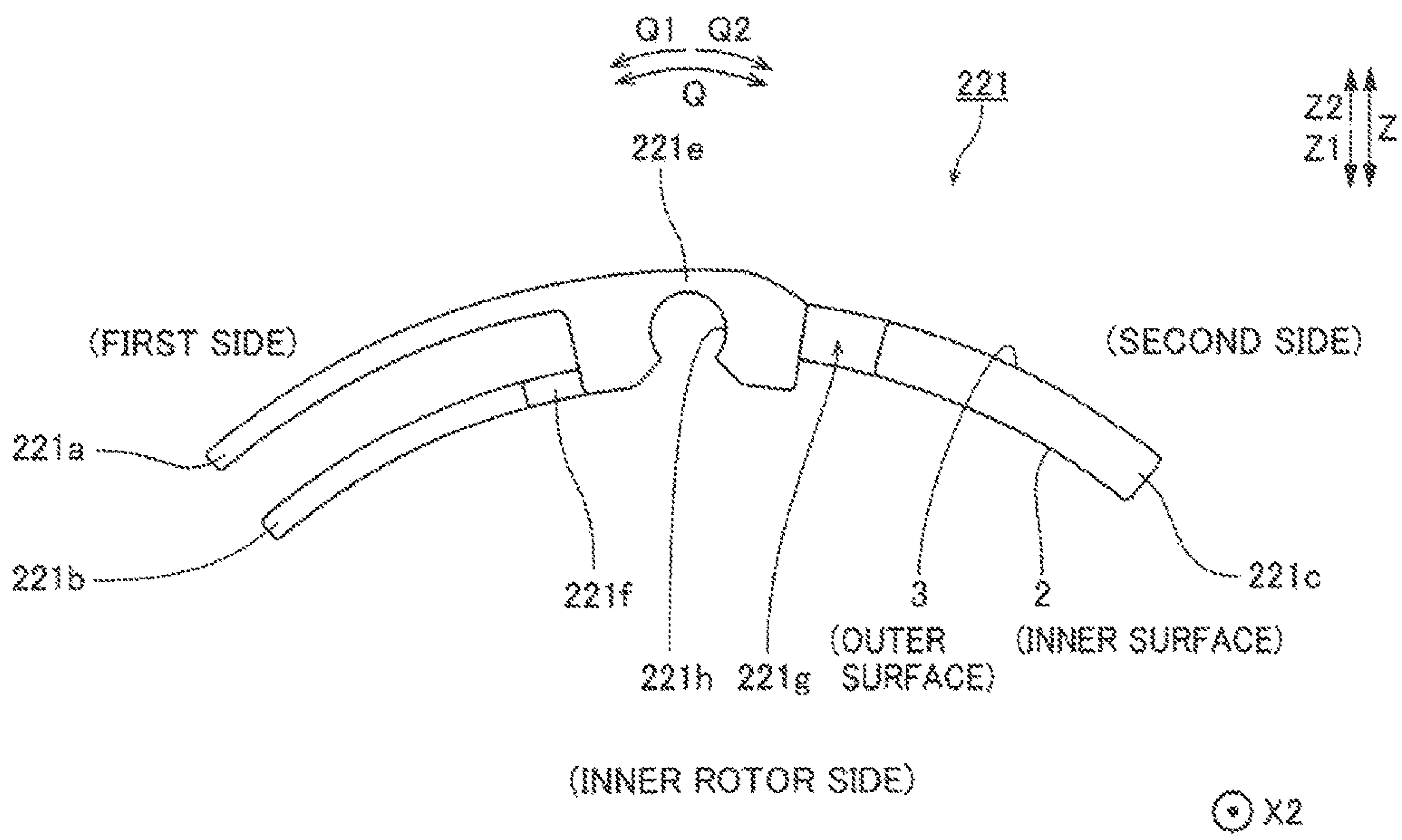

Q1 Q2
Q
221
Z2
Z1
Z
221e
(FIRST SIDE)
(SECOND SIDE)
221a
221b
221f
221h
221g
3
(OUTER SURFACE)
2
(INNER SURFACE)
221c
(INNER ROTOR SIDE)
X2

FIG.12

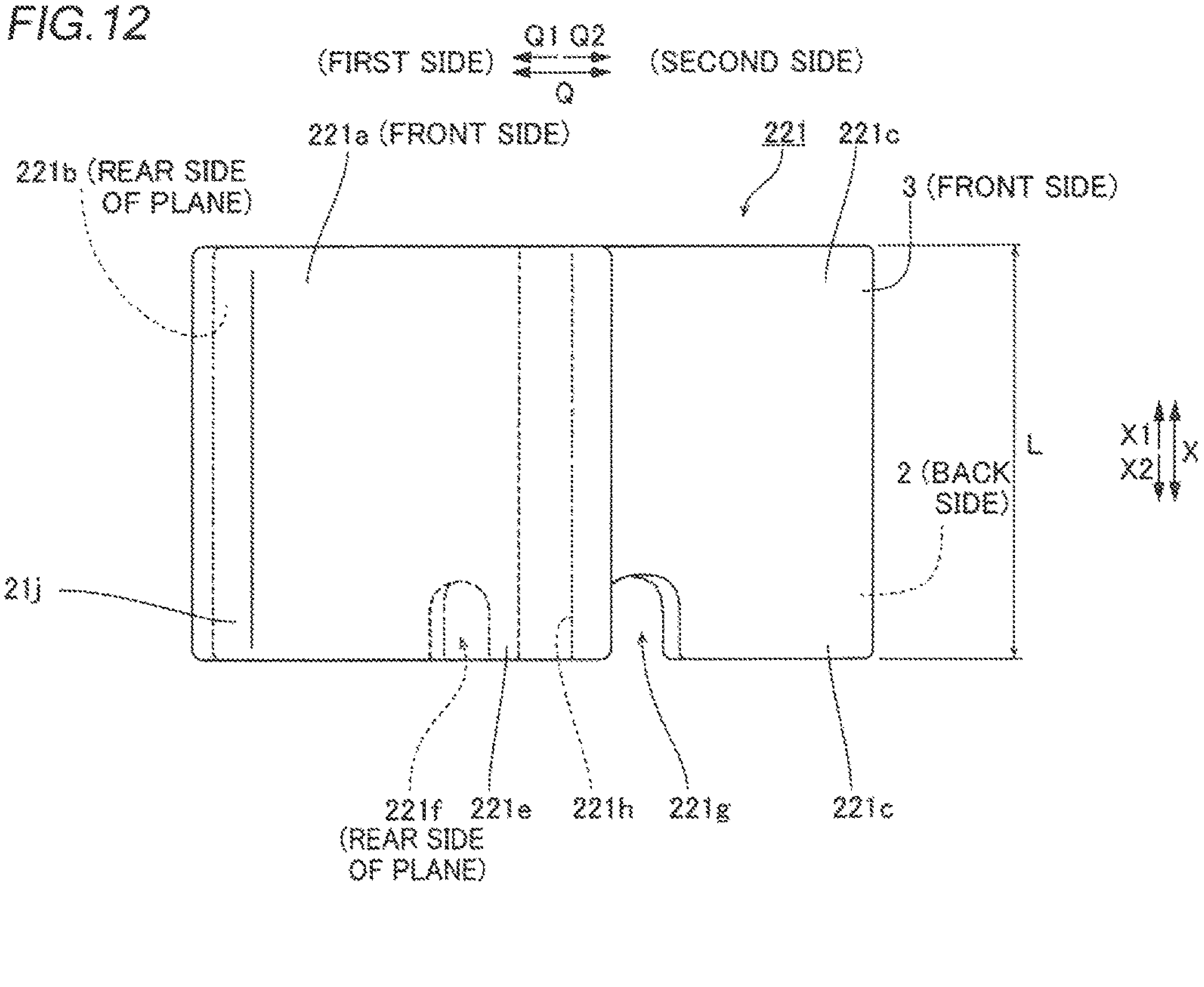
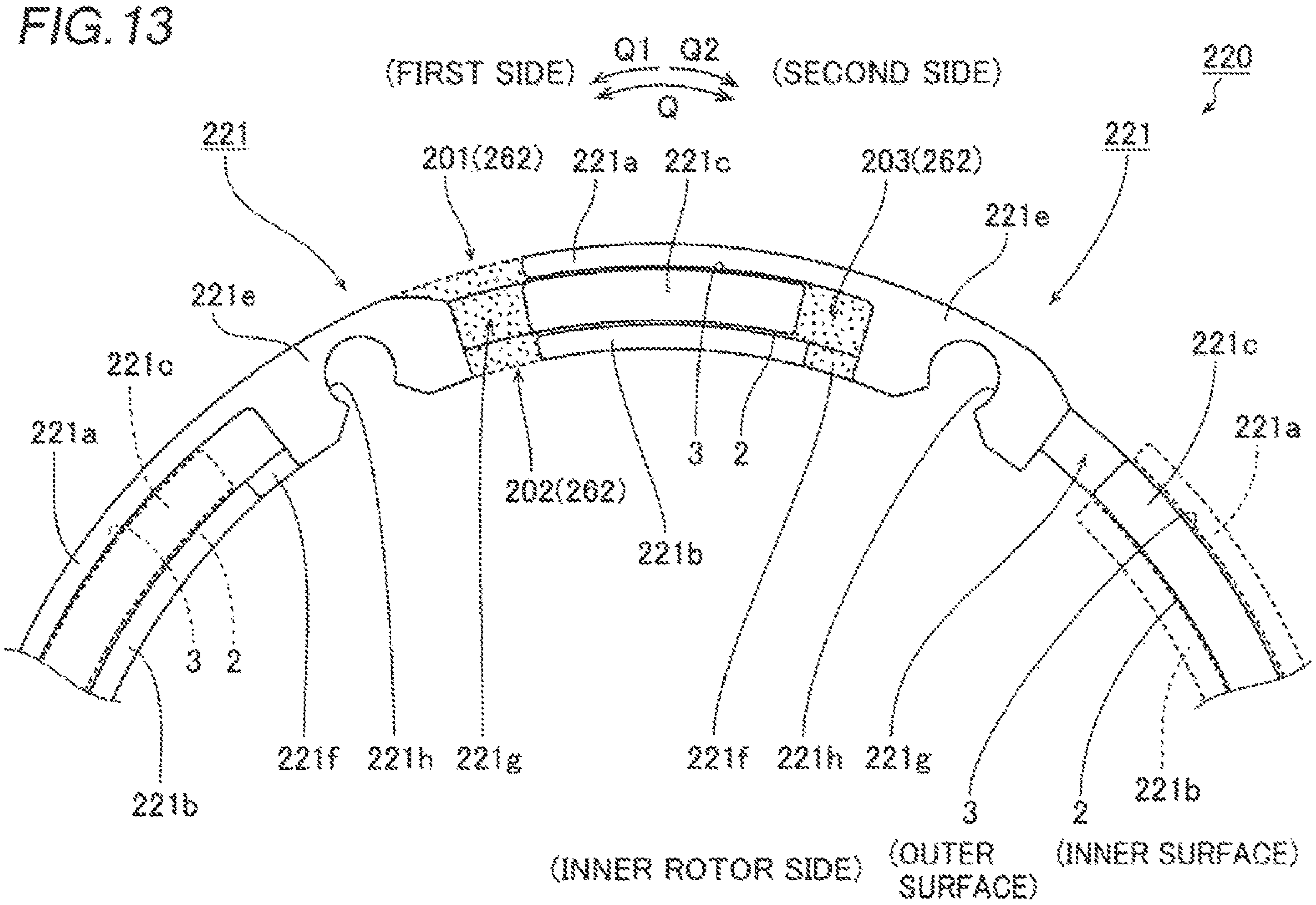
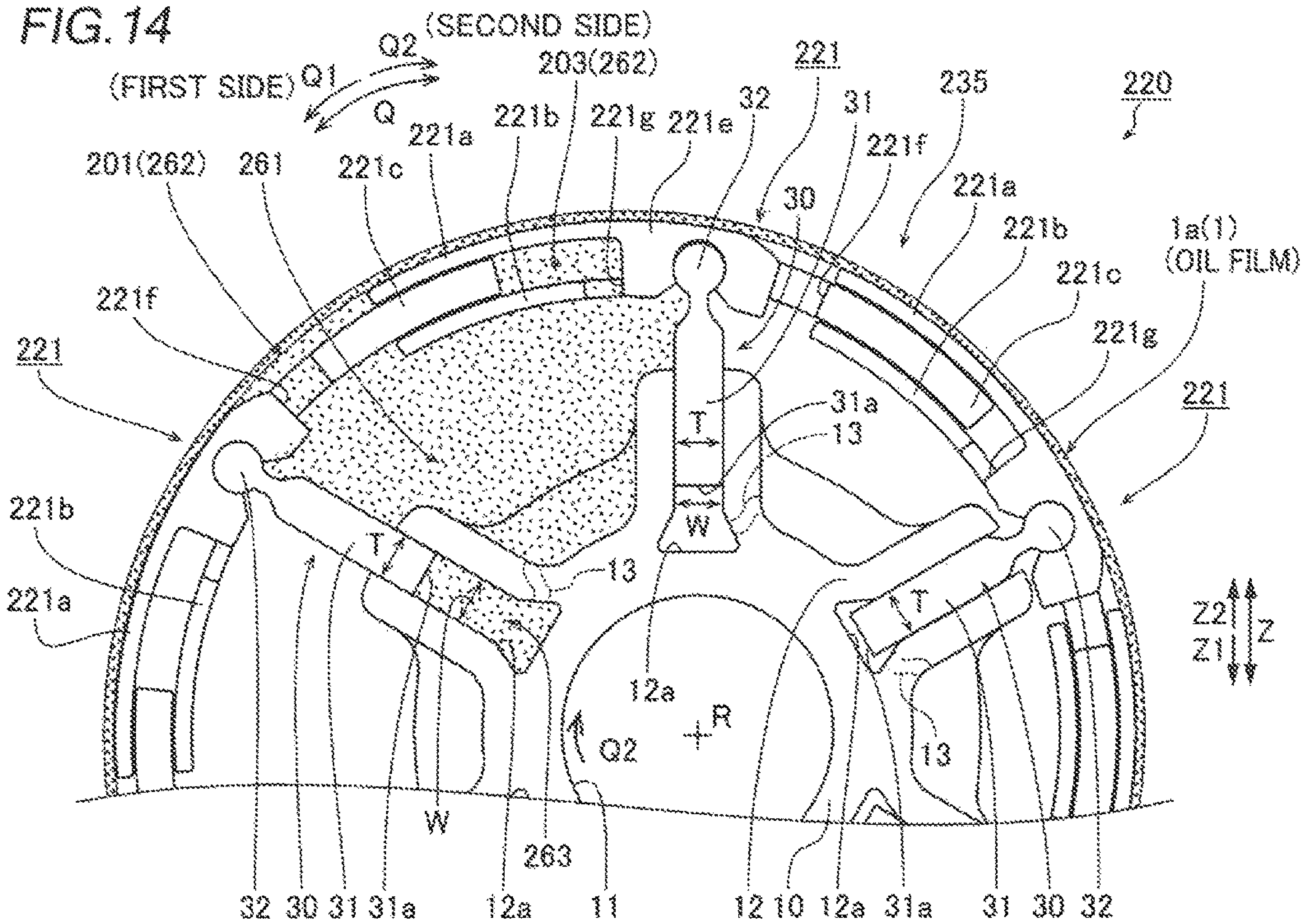

(FIRST SIDE)
Q1 Q2
Q
(SECOND SIDE)
221a (FRONT SIDE)
221
221c
221b (REAR SIDE OF PLANE)
3 (FRONT SIDE)
L
X1
X2
X
2 (BACK SIDE)
21j
221f (REAR SIDE OF PLANE)
221e
221h
221g
221c

FIG. 13



(FIRST SIDE)
Q1
Q2
(SECOND SIDE)
Q
220
221
201(262)
221a
221c
203(262)
221e
221c
221a
3
2
202(262)
221b
221f
221h
221g
(INNER ROTOR SIDE)
(OUTER SURFACE)
(INNER SURFACE)

FIG. 14



(SECOND SIDE)
(FIRST SIDE)
Q1
Q2
Q
203(262)
221
235
220
201(262)
261
221c
221a
221b
221g
221e
32
31
30
221f
1a(1)
(OIL FILM)
31a
13
T
W
12a
R
Z2
Z1
Z
263
11
12
10

FIG. 15

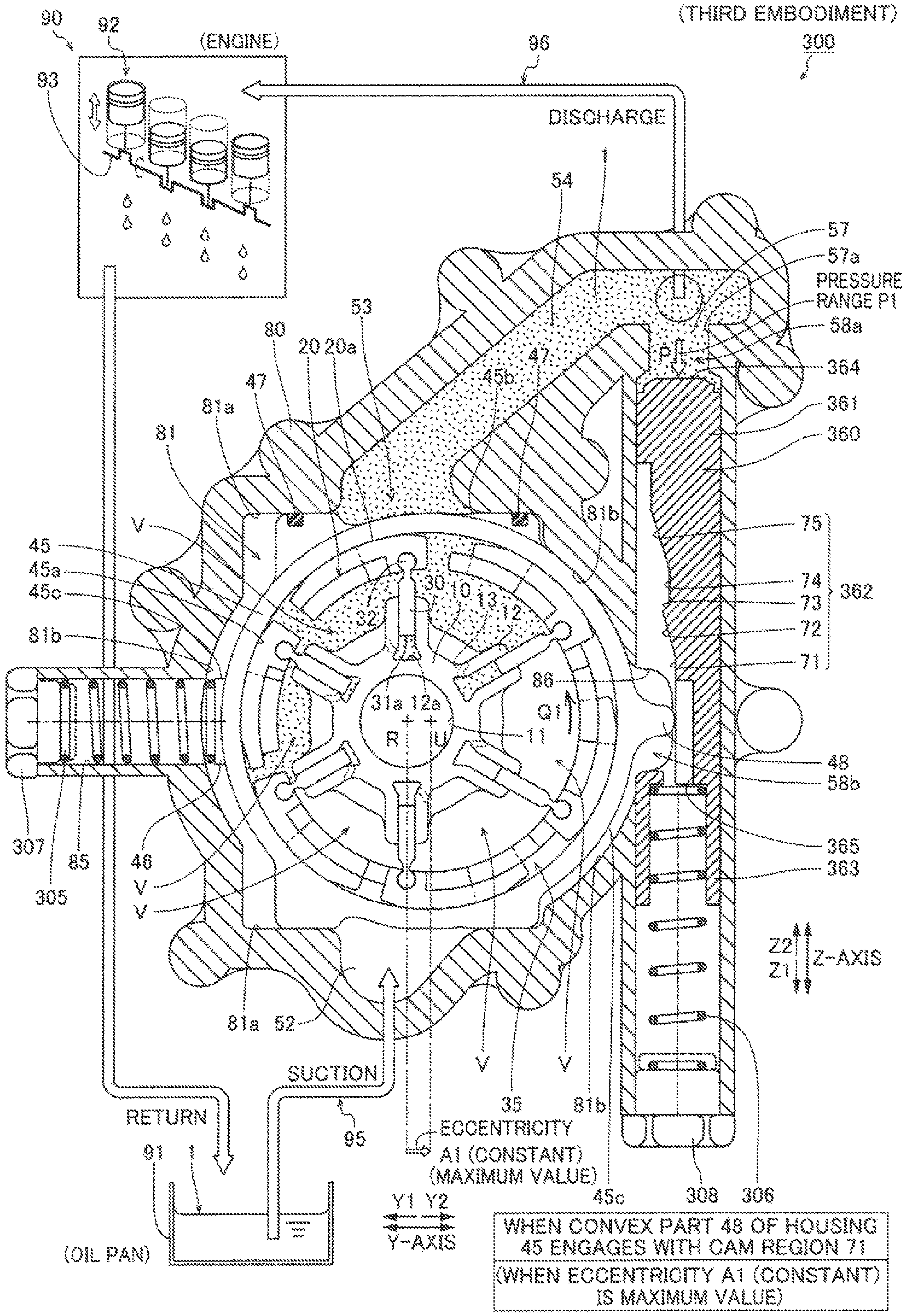

(THIRD EMBODIMENT)
300
(ENGINE)
DISCHARGE
PRESSURE RANGE P1
SUCTION
RETURN
(OIL PAN)
ECCENTRICITY A1 (CONSTANT) (MAXIMUM VALUE)
Y1 Y2
Y-AXIS
Z2
Z1
Z-AXIS
WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 71
(WHEN ECCENTRICITY A1 (CONSTANT) IS MAXIMUM VALUE)

FIG.16

(ENLARGED VIEW OF MAIN PART OF PUMP BODY)

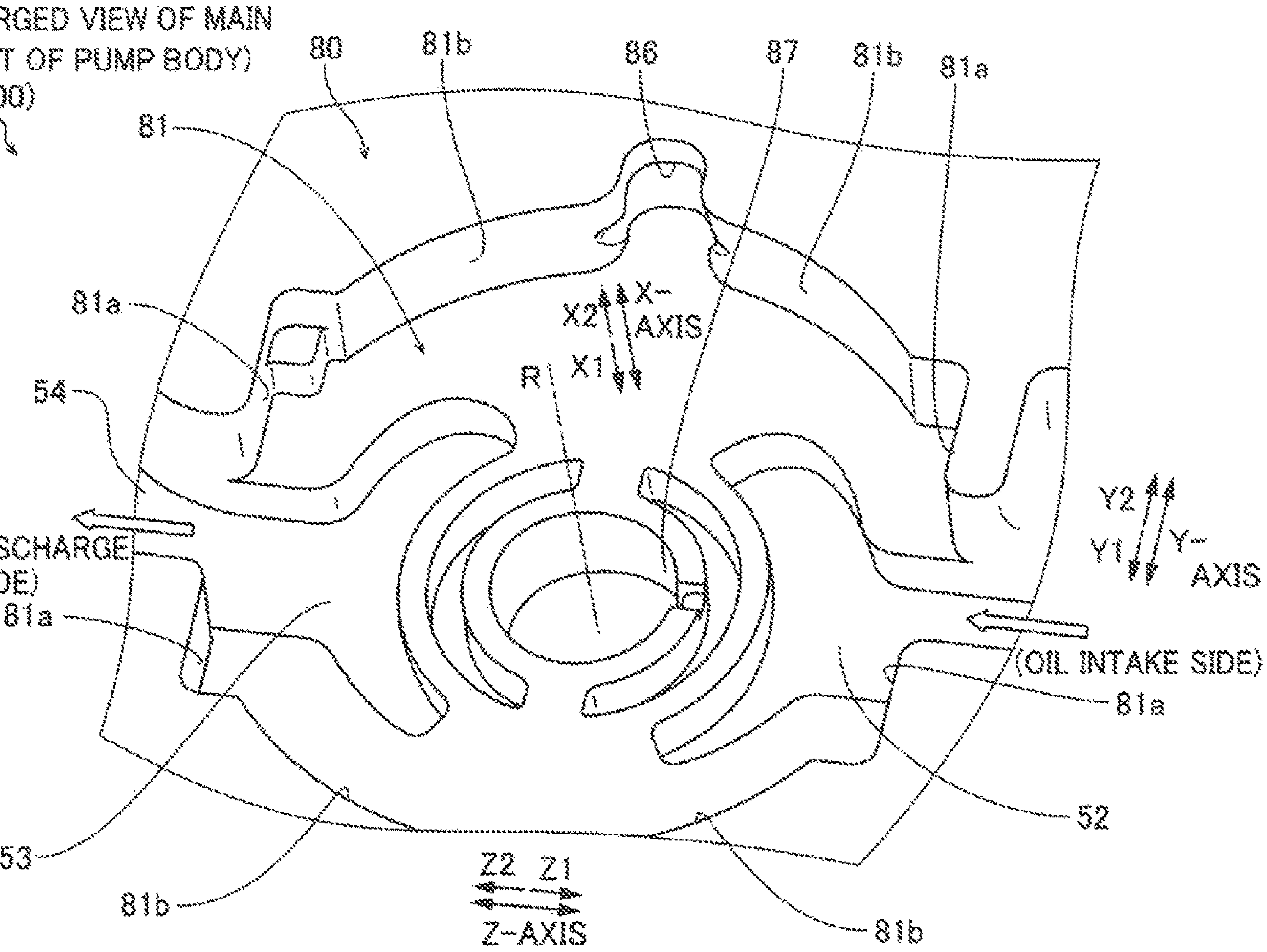


FIG.17

(SPOOL MEMBER)

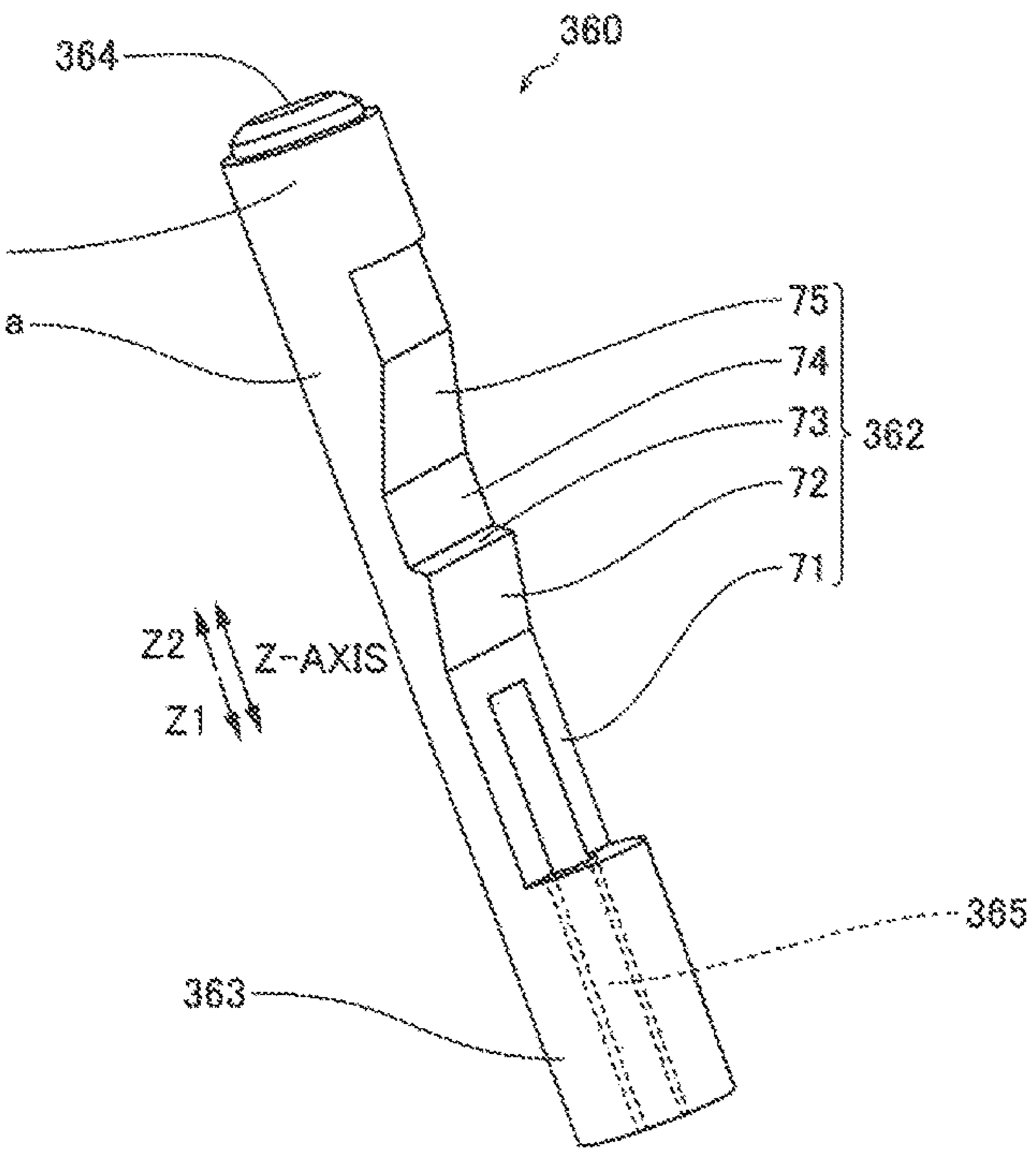


FIG. 18

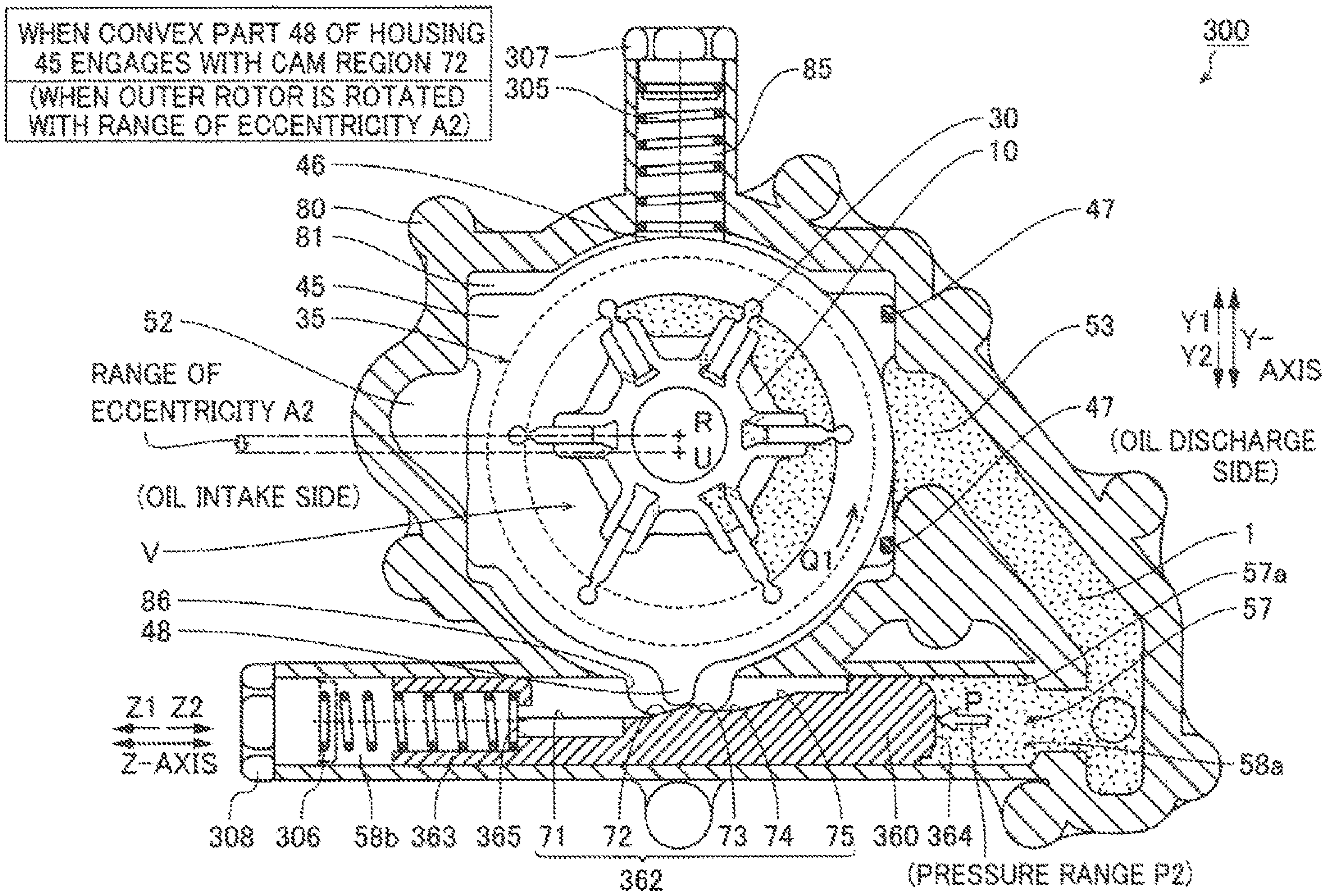

WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 72
(WHEN OUTER ROTOR IS ROTATED WITH RANGE OF ECCENTRICITY A2)
300
307
305
85
30
10
46
80
81
45
35
52
47
53
Y1
Y2
Y-AXIS
RANGE OF ECCENTRICITY A2
R
U
(OIL DISCHARGE SIDE)
(OIL INTAKE SIDE)
V
Q1
1
57a
57
86
48
Z1 Z2
Z-AXIS
P
58a
308 306 58b 363 365 71 72 73 74 75 360 364
362
(PRESSURE RANGE P2)

FIG. 19

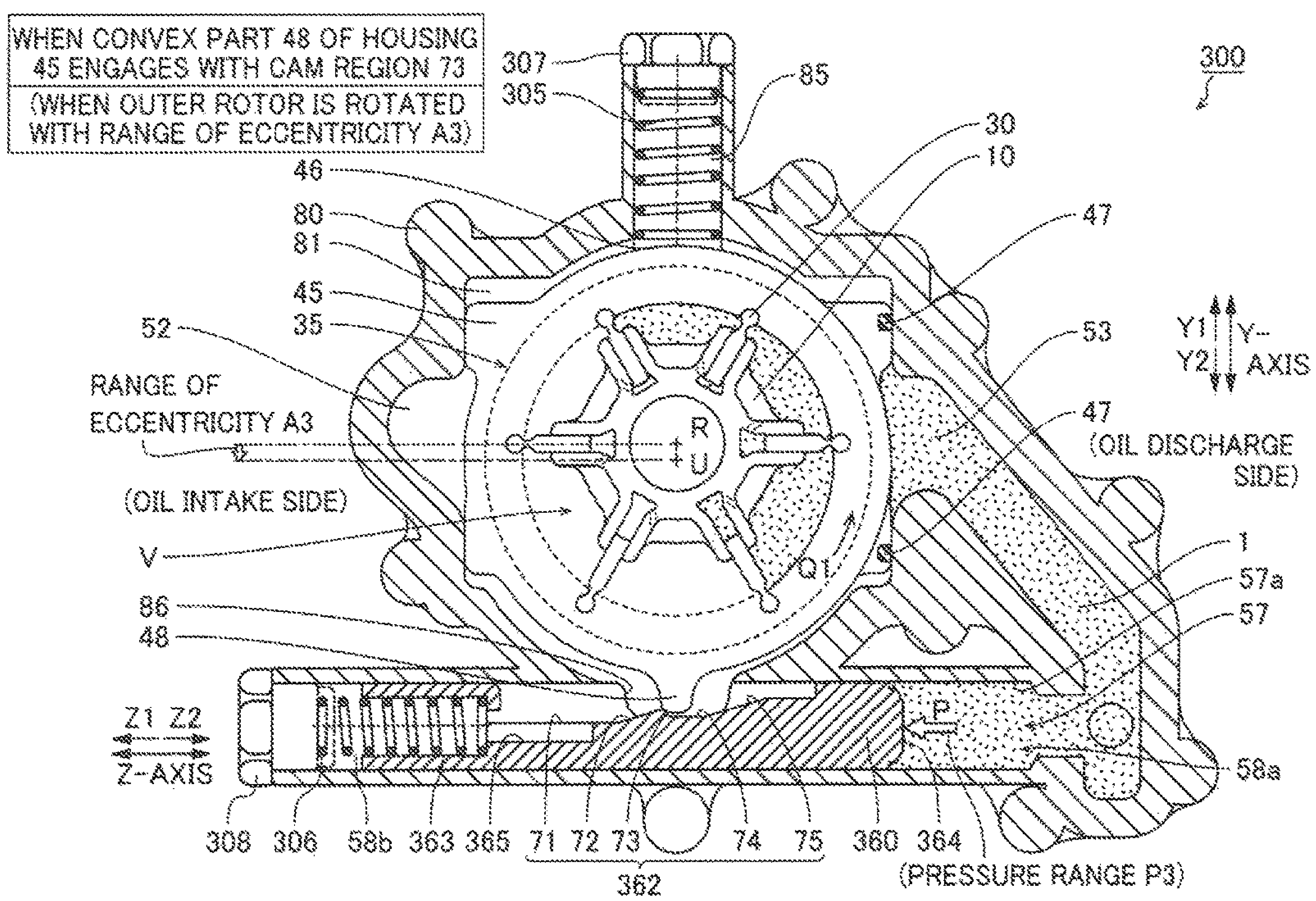

WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 73
(WHEN OUTER ROTOR IS ROTATED WITH RANGE OF ECCENTRICITY A3)
300
307
305
85
30
10
46
80
81
45
35
52
47
53
Y1
Y2
Y-AXIS
RANGE OF ECCENTRICITY A3
R
U
(OIL DISCHARGE SIDE)
(OIL INTAKE SIDE)
V
Q1
1
57a
57
86
48
Z1 Z2
Z-AXIS
P
58a
308 306 58b 363 365 71 72 73 74 75 360 364
362
(PRESSURE RANGE P3)

FIG.20

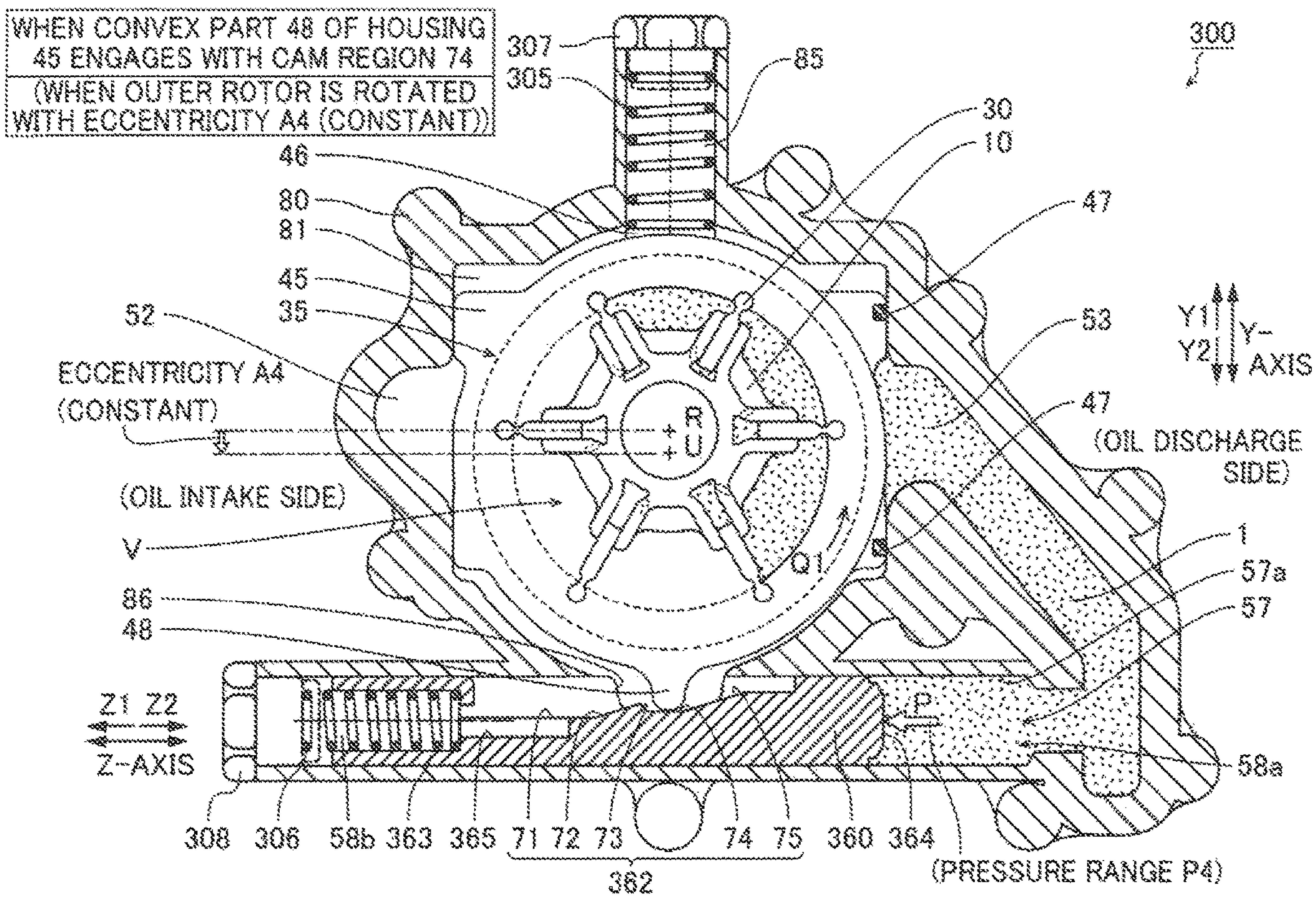

WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 74
(WHEN OUTER ROTOR IS ROTATED WITH ECCENTRICITY A4 (CONSTANT))
300
307
305
85
30
10
46
80
81
45
35
47
52
53
Y1
Y2
Y-AXIS
ECCENTRICITY A4
(CONSTANT)
R
U
(OIL DISCHARGE SIDE)
(OIL INTAKE SIDE)
V
Q1
1
57a
57
86
48
P
Z1 Z2
Z-AXIS
58a
308
306
58b
363
365
71
72
73
74
75
360
364
362
(PRESSURE RANGE P4)

FIG.21

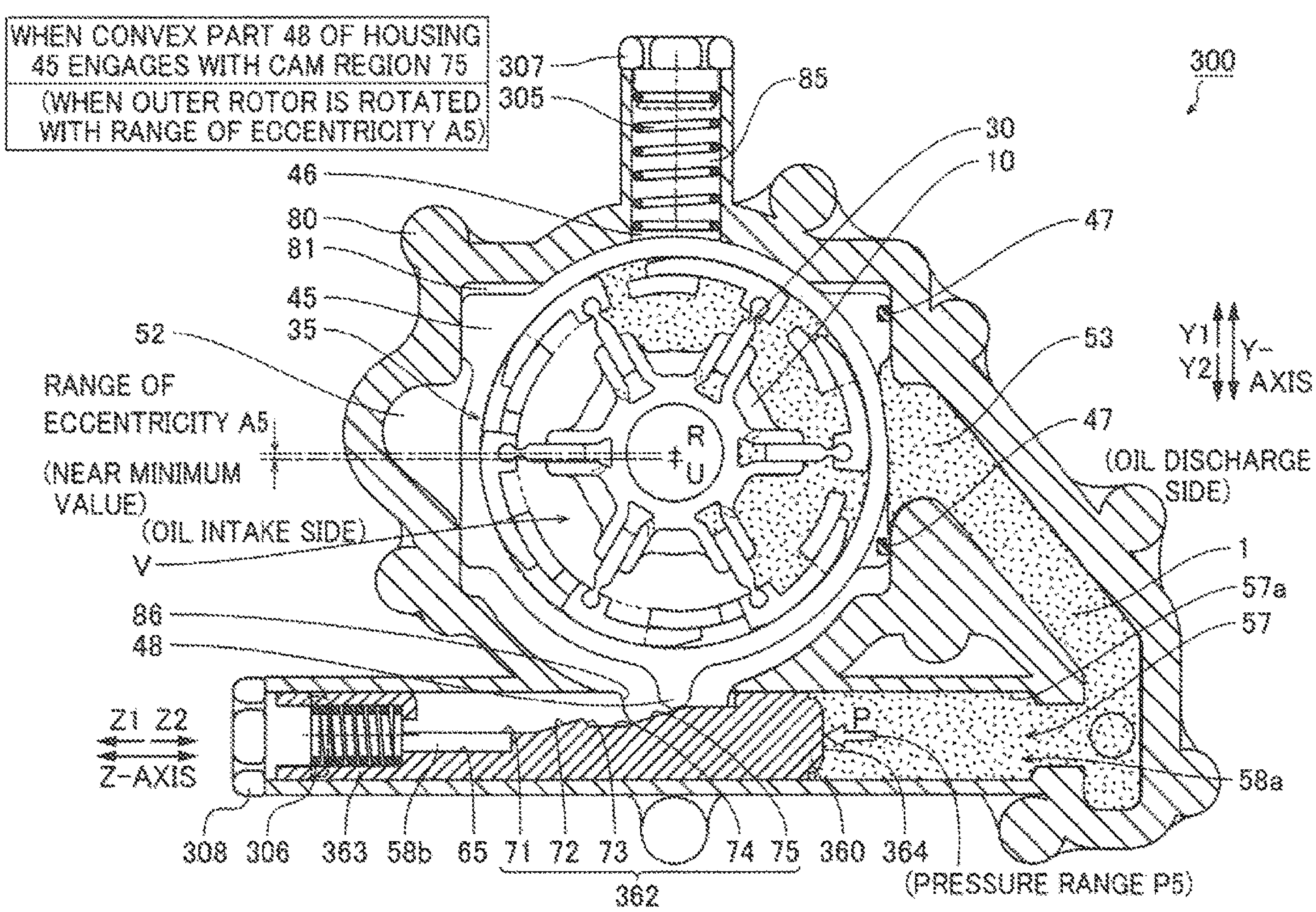

WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 75
(WHEN OUTER ROTOR IS ROTATED WITH RANGE OF ECCENTRICITY A5)
300
307
305
85
30
10
46
80
81
47
45
35
52
53
Y1
Y2
Y-AXIS
RANGE OF ECCENTRICITY A5
(NEAR MINIMUM VALUE)
R
U
47
(OIL DISCHARGE SIDE)
(OIL INTAKE SIDE)
V
1
57a
57
86
48
P
Z1 Z2
Z-AXIS
58a
308
306
363
58b
65
71
72
73
74
75
360
364
362
(PRESSURE RANGE P5)

FIG.22

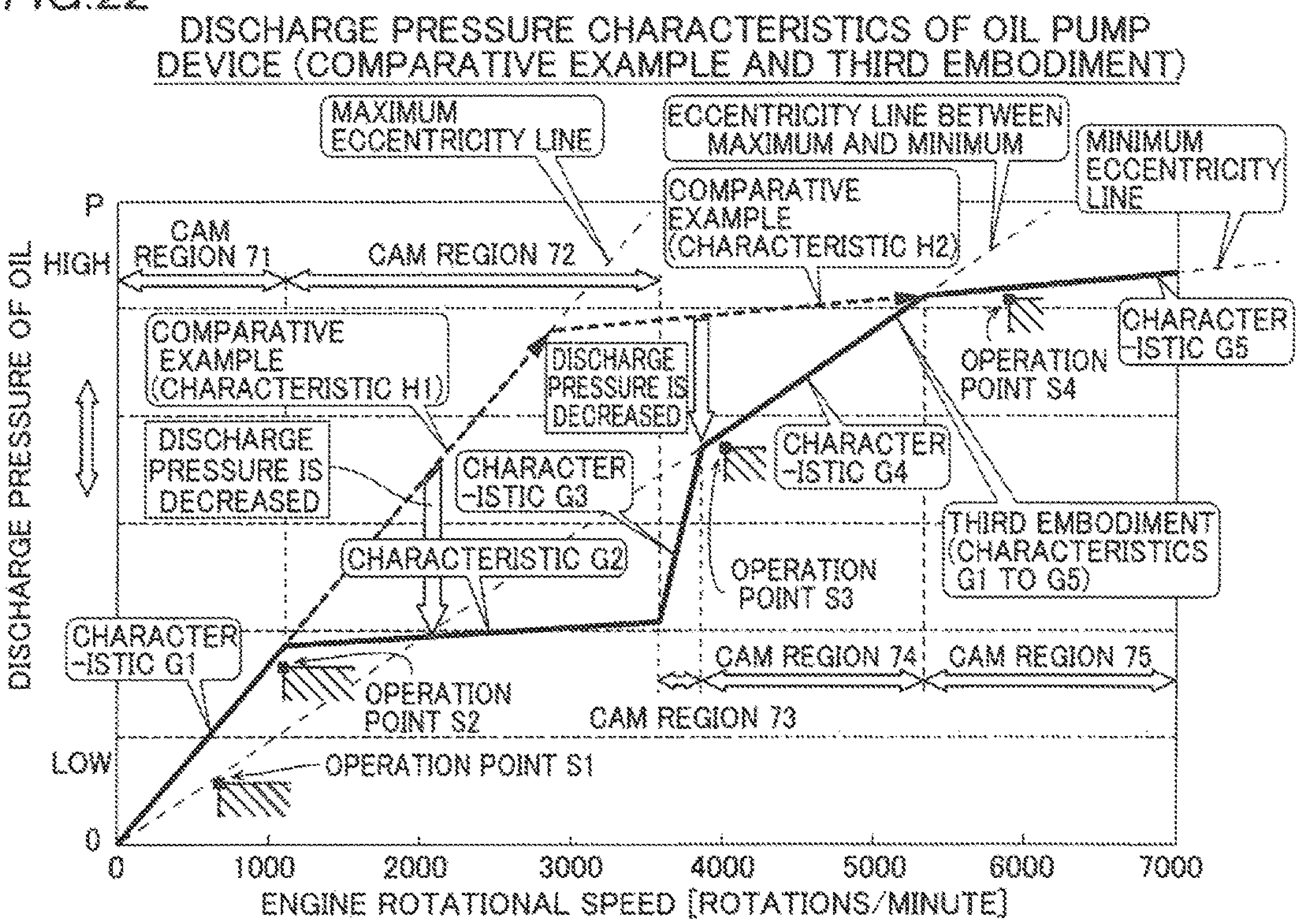

DISCHARGE PRESSURE CHARACTERISTICS OF OIL PUMP DEVICE (COMPARATIVE EXAMPLE AND THIRD EMBODIMENT)
MAXIMUM ECCENTRICITY LINE
ECCENTRICITY LINE BETWEEN MAXIMUM AND MINIMUM
MINIMUM ECCENTRICITY LINE
COMPARATIVE EXAMPLE (CHARACTERISTIC H2)
P
HIGH
CAM REGION 71
CAM REGION 72
COMPARATIVE EXAMPLE (CHARACTERISTIC H1)
DISCHARGE PRESSURE IS DECREASED
DISCHARGE PRESSURE IS DECREASED
CHARACTER -ISTIC G5
OPERATION POINT S4
CHARACTER -ISTIC G4
CHARACTER -ISTIC G3
THIRD EMBODIMENT (CHARACTERISTICS G1 TO G5)
CHARACTERISTIC G2
OPERATION POINT S3
CHARACTER -ISTIC G1
OPERATION POINT S2
CAM REGION 74
CAM REGION 75
CAM REGION 73
LOW
OPERATION POINT S1
0
DISCHARGE PRESSURE OF OIL
0 1000 2000 3000 4000 5000 6000 7000
ENGINE ROTATIONAL SPEED [ROTATIONS/MINUTE]

FIG.23

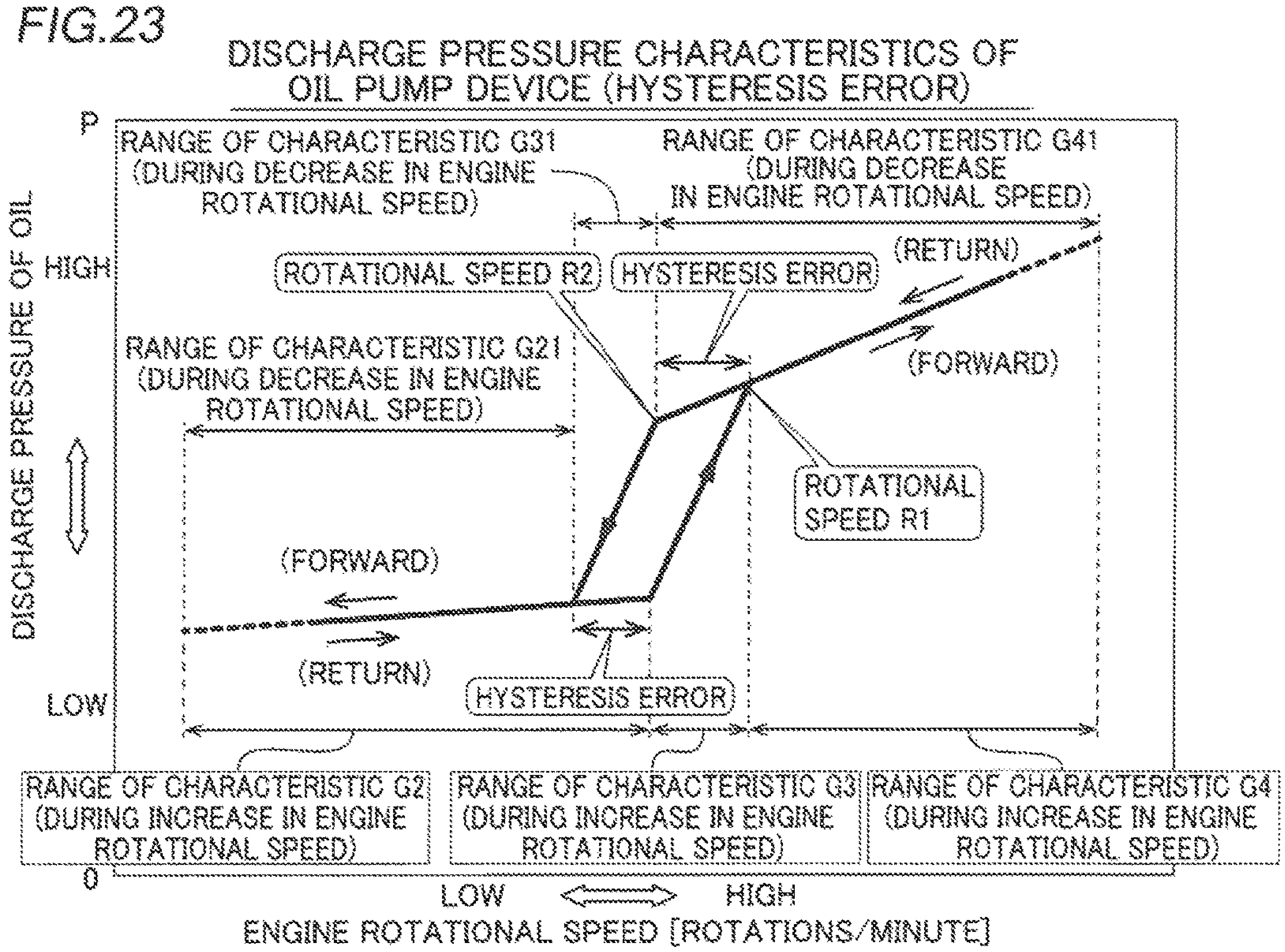

DISCHARGE PRESSURE CHARACTERISTICS OF OIL PUMP DEVICE (HYSTERESIS ERROR)
P
RANGE OF CHARACTERISTIC G31 (DURING DECREASE IN ENGINE ROTATIONAL SPEED)
RANGE OF CHARACTERISTIC G41 (DURING DECREASE IN ENGINE ROTATIONAL SPEED)
HIGH
ROTATIONAL SPEED R2
HYSTERESIS ERROR
(RETURN)
(FORWARD)
RANGE OF CHARACTERISTIC G21 (DURING DECREASE IN ENGINE ROTATIONAL SPEED)
ROTATIONAL SPEED R1
(FORWARD)
(RETURN)
HYSTERESIS ERROR
LOW
DISCHARGE PRESSURE OF OIL
RANGE OF CHARACTERISTIC G2 (DURING INCREASE IN ENGINE ROTATIONAL SPEED)
RANGE OF CHARACTERISTIC G3 (DURING INCREASE IN ENGINE ROTATIONAL SPEED)
RANGE OF CHARACTERISTIC G4 (DURING INCREASE IN ENGINE ROTATIONAL SPEED)
0
LOW
HIGH
ENGINE ROTATIONAL SPEED [ROTATIONS/MINUTE]

FIG.24

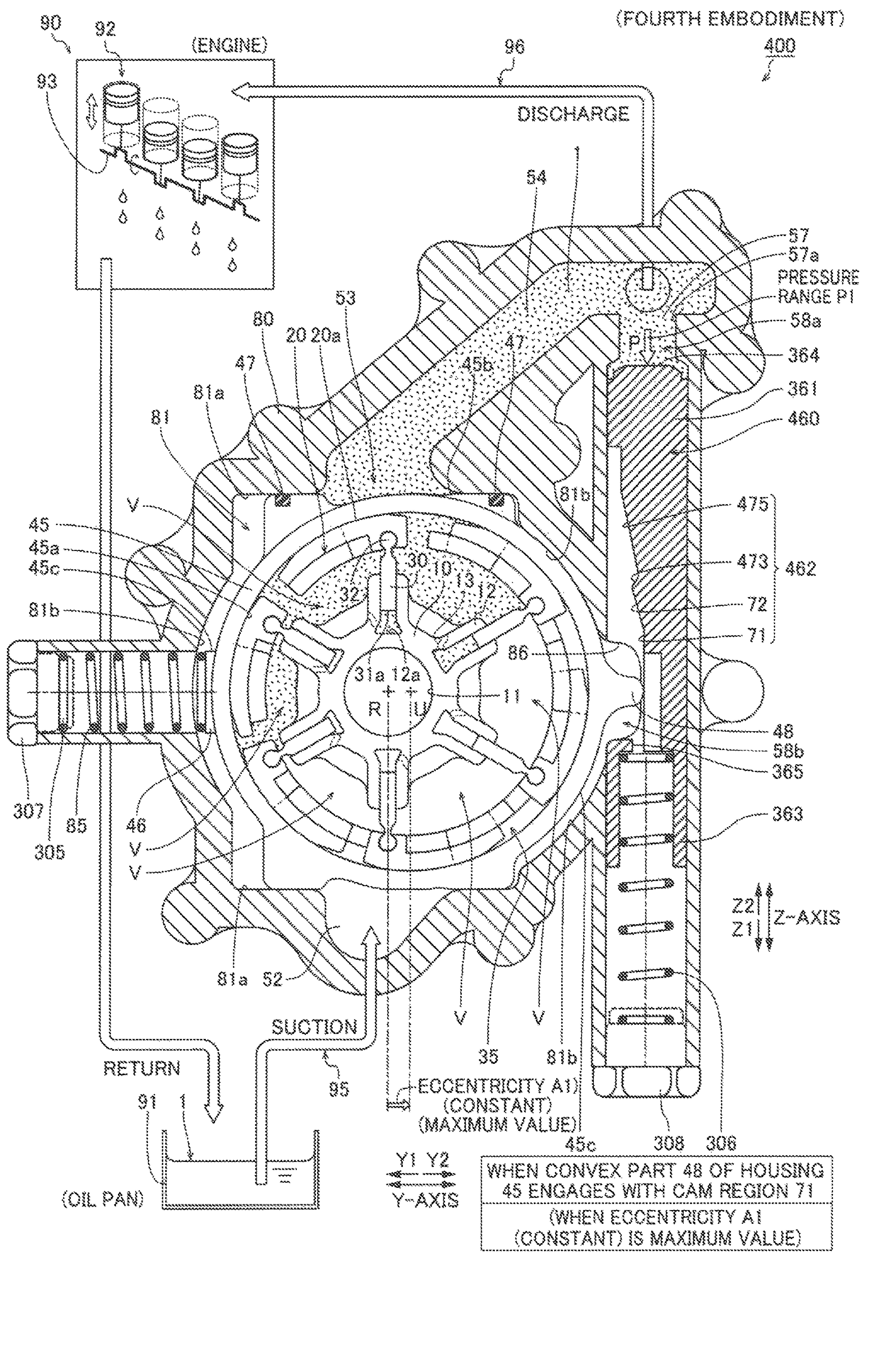
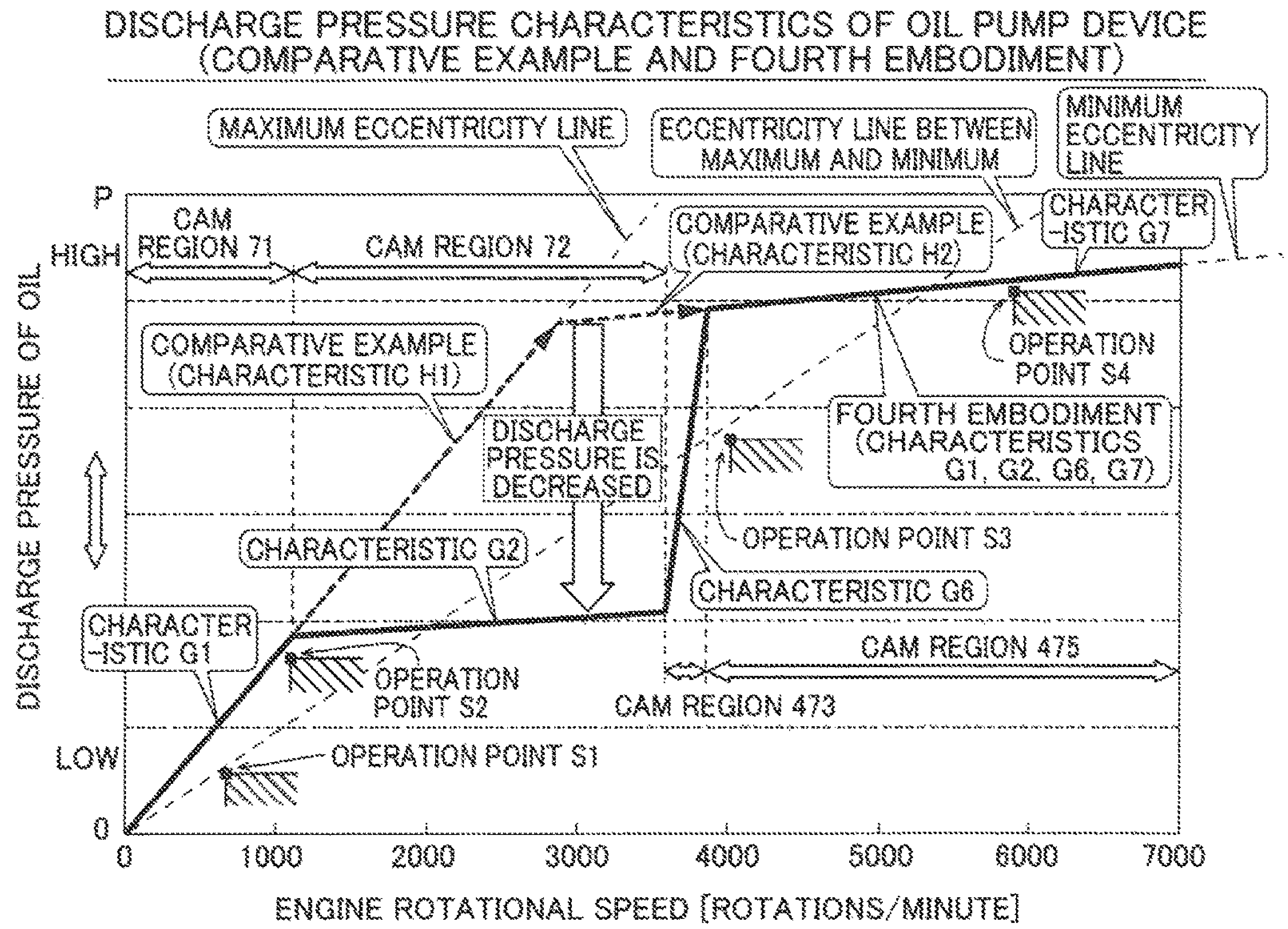
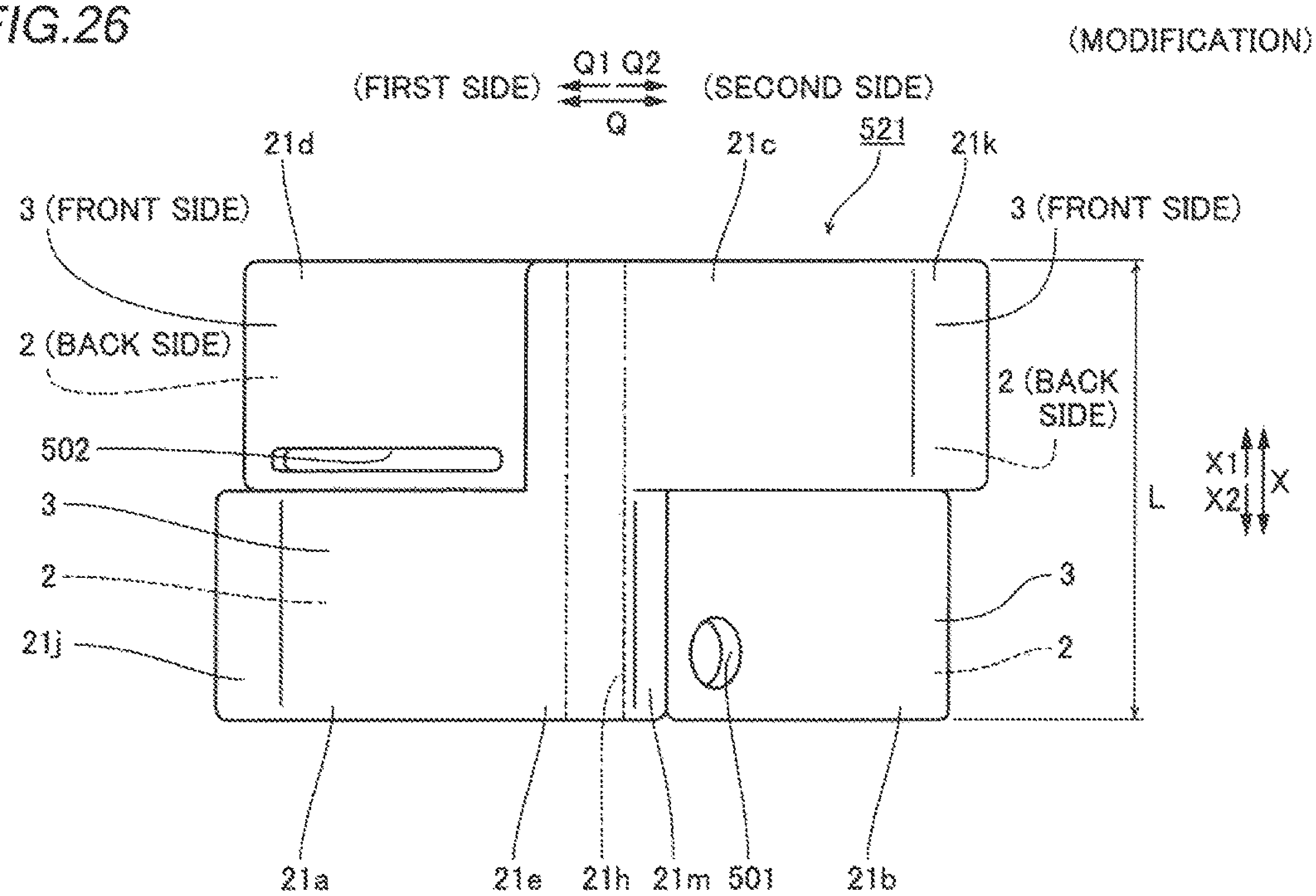

(FOURTH EMBODIMENT)
400
90
92
(ENGINE)
96
93
DISCHARGE
54
57
57a
PRESSURE RANGE P1
58a
364
361
460
475
473
462
72
71
53
80
20 20a
47
45b
81a
81
81b
V
45
45a
45c
30
10
32
13
12
86
31a 12a
R
U
11
48
58b
365
363
307
305
85
46
Z2
Z1
Z-AXIS
81a 52
SUCTION
RETURN
95
35
81b
ECCENTRICITY A1 (CONSTANT) (MAXIMUM VALUE)
91 1
(OIL PAN)
45c
308
306
Y1 Y2
Y-AXIS
WHEN CONVEX PART 48 OF HOUSING 45 ENGAGES WITH CAM REGION 71
(WHEN ECCENTRICITY A1 (CONSTANT) IS MAXIMUM VALUE)

FIG.25



DISCHARGE PRESSURE CHARACTERISTICS OF OIL PUMP DEVICE
(COMPARATIVE EXAMPLE AND FOURTH EMBODIMENT)
MAXIMUM ECCENTRICITY LINE
ECCENTRICITY LINE BETWEEN MAXIMUM AND MINIMUM
MINIMUM ECCENTRICITY LINE
CHARACTER-ISTIC G7
COMPARATIVE EXAMPLE (CHARACTERISTIC H2)
CAM REGION 71
CAM REGION 72
COMPARATIVE EXAMPLE (CHARACTERISTIC H1)
DISCHARGE PRESSURE IS DECREASED
OPERATION POINT S4
FOURTH EMBODIMENT (CHARACTERISTICS G1, G2, G6, G7)
OPERATION POINT S3
CHARACTERISTIC G2
CHARACTERISTIC G6
CHARACTER-ISTIC G1
OPERATION POINT S2
CAM REGION 475
CAM REGION 473
OPERATION POINT S1
P
HIGH
LOW
0
DISCHARGE PRESSURE OF OIL
0 1000 2000 3000 4000 5000 6000 7000
ENGINE ROTATIONAL SPEED [ROTATIONS/MINUTE]

FIG.26



(MODIFICATION)
(FIRST SIDE) Q1 Q2 Q (SECOND SIDE)
21d
21c
521
21k
3 (FRONT SIDE)
2 (BACK SIDE)
502
3 (FRONT SIDE)
2 (BACK SIDE)
3
2
21j
L
X1
X2
X
3
2
21a
21e
21h
21m
501
21b

OIL PUMP

TECHNICAL FIELD

The present invention relates to an oil pump, and more particularly, it relates to an oil pump including an inner rotor, an outer rotor, and multiple vanes connecting the outer periphery of the inner rotor and the inner periphery of the outer rotor.

BACKGROUND ART

In general, an oil pump including an inner rotor, an outer rotor, and multiple vanes connecting the outer periphery of the inner rotor and the inner periphery of the outer rotor is known. Such an oil pump is disclosed in Japanese Patent Laying-Open No. 2012-255439, for example.

In Japanese Patent Laying-Open No. 2012-255439, there is disclosed a pendulum-slider pump (oil pump) including an inner rotor rotationally driven, an outer rotor arranged to surround the inner rotor, configured to be rotatable outside the inner rotor, and multiple pendulums (vanes) connecting the outer periphery of the inner rotor and the inner periphery of the outer rotor. In this pendulum-slider pump described in Japanese Patent Laying-Open No. 2012-255439, a first end (tip end) of each of the pendulums is hinged to the outer periphery of the inner rotor, and a second end (base part) of each of the pendulums is fitted into a recess part of the outer rotor formed to correspond to each of the pendulums. In response to relative eccentricity between the inner rotor and the outer rotor, each of the pendulums is sequentially rotationally moved while swinging about a connecting part with the inner rotor along with the rotation of the inner rotor, and the second end of each of the pendulums is displaced to freely appear from and disappear into the recess part of the outer rotor. At this time, multiple volume chambers individually partitioned by the pendulums are sequentially repetitively deformed along with the rotation of the inner rotor, thereby providing a pumping function.

Furthermore, in order to cause the pendulums to swing (turn), an intermediate part of each of the pendulums connecting the first end and the second end is narrower than both ends (the first end and the second end). Thus, the intermediate part entering the recess part of the outer rotor is prevented from contacting with an inner wall of the recess part due to swing (inclination) of the pendulums. In addition, each of the pendulums swings, whereby both the inner rotor and the outer rotor having relative eccentricity smoothly rotate.

PRIOR ART

Patent Document

Patent Document 1: Japanese Patent Laying-Open No. 2012-255439

SUMMARY OF THE INVENTION

Problem to be Solved by the Invention

In the pendulum-slider pump (oil pump) described in Japanese Patent Laying-Open No. 2012-255439, although the multiple volume chambers individually partitioned by the pendulums are sequentially repetitively deformed along with the rotation of the inner rotor, thereby providing the pumping function, there is such a problem that a net rate of

discharge of oil per unit rotation cannot be sufficiently increased because of the difficulty of sufficiently utilizing the amount of change in volume other than the volume of the multiple volume chambers partitioned by the pendulums.

The present invention has been proposed in order to solve the aforementioned problem, and an object of the present invention is to provide an oil pump capable of sufficiently increasing a net rate of discharge of oil per unit rotation.

Means for Solving the Problem

In order to attain the aforementioned object, an oil pump according to an aspect of the present invention includes a rotatable inner rotor that includes a vane-housing unit housing multiple vanes so as to be capable of sliding in a radial direction, a rotatable annular outer rotor that includes multiple vane-connecting parts connecting tip ends of the multiple vanes on the outside in the radial direction, first volume-changing parts, which are provided between the inner rotor and the outer rotor, and the first volume of which is changed in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function, and second volume-changing parts, which are provided in the outer rotor, and the second volume of which is changed by a change in a distance between adjacent vane-connecting parts in a circumferential direction in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function.

As hereinabove described, the oil pump according to the aspect of the present invention includes the inner rotor that includes the vane-housing unit housing the multiple vanes so as to be capable of sliding in the radial direction, the outer rotor that includes the multiple vane-connecting parts connecting the tip ends of the multiple vanes on the outside in the radial direction, the first volume-changing parts, the first volume of which is changed in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing the pumping function, and the second volume-changing parts, which are provided in the outer rotor, and the second volume of which is changed by the change in the distance between the adjacent vane-connecting parts in the circumferential direction in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing the pumping function. Thus, in addition to the highly-efficient pumping of the first volume-changing parts partitioned by the vanes, the pumping of the second volume-changing parts newly provided in the outer rotor can be effectively utilized. Therefore, a net rate of discharge of oil per unit rotation in the oil pump can be sufficiently increased. Consequently, the pumping efficiency can be improved. When compared at the same rate of discharge, the oil pump can be reduced in size, and hence the mountability of the oil pump to a device (apparatus) can be improved. Furthermore, the oil pump is reduced in size so that a mechanical loss during driving of the oil pump can be reduced, and hence the load of a drive source driving the oil pump is reduced so that the energy can be saved.

The aforementioned oil pump according to the aspect preferably further includes third volume-changing parts, the third volume of which in the vane-housing unit of the inner rotor is changed by slide of the multiple vanes in the radial direction in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function. According to this structure, the oil pump can be configured to incorporate the change in the volume of the third volume-changing parts in the vane-housing unit by the linear slide of the vanes in the radial direction with respect to the vane-housing unit into the pumping including the suction and discharge of the oil in addition to the pumping of the first volume-changing parts and the second volume-changing parts, and hence the pumping of the third volume-changing parts is effectively added so that the rate of discharge of the oil per unit rotation that the oil pump has can be further increased. Consequently, the oil pump can be further reduced in size. In the aforementioned Patent Document 1, the intermediate part of each of the swinging pendulums is narrower than both ends, and hence a new space part (volume part) is collaterally generated between the narrowed intermediate part of each of the pendulums and the recess part of the outer rotor when the second end (base part) of each of the pendulums deeply enters the recess part so that a volume chamber surrounded by the base part and the recess part is minimized. In the aforementioned oil pump according to the aspect, on the other hand, the vanes linearly sliding in the radial direction are used, and hence it is not necessary to narrow an intermediate part of each of the vanes that appears from and disappears into the vane-housing unit. Therefore, no minus factor (wasted work) to newly increase the volume (newly form volume chambers) in parts of the third volume-changing parts on the side of the first volume-changing parts is generated during a decrease change in the third volume of the third volume-changing parts, and hence the changes in the volumes of the first, second, and third volume-changing parts can effectively work on the pumping of the entire oil pump.

The aforementioned structure further including the third volume-changing parts preferably further includes a suction port that suctions oil and a discharge port that discharges the oil, and in the suction port, the third volume in the vane-housing unit of the inner rotor is preferably gradually increased by gradual slide of the vanes, housed in the vane-housing unit, to the outside in the radial direction while in the discharge port, the third volume in the vane-housing unit of the inner rotor is preferably gradually decreased by the gradual slide of the vanes, housed in the vane-housing unit, to the inside in the radial direction. According to this structure, the change in the third volume generated by repeating appearance (increase) from and disappearance (decrease) into the vane-housing unit along with back-and-forth linear movement of the vanes to the outside and the inside in the radial direction can be easily utilized as pumping. At this time, the drive force of the oil pump can be converted to not only the change in the volume (first volume) of the first volume-changing parts and the change in the volume (second volume) of the second volume-changing parts following the slide of the vanes but also the change in the volume (third volume) of the third volume-changing parts following the slide of the vanes, and hence the mechanical efficiency of the oil pump can be improved without wasting the drive force.

In the aforementioned structure further including the third volume-changing parts, the thickness of each of parts of the vanes housed in the vane-housing unit is preferably constant. According to this structure, the vanes including the parts housed in the vane-housing unit, the thickness of which is constant, are used, whereby the vanes can stably slide in the radial direction without backlash in the vane-housing unit. Furthermore, no backlash of the vanes is generated during back-and-forth movement, and hence the airtightness can be improved when the third volume-changing parts (third volume) repeat their enlargement (increase) and shrinkage (decrease). Thus, the pumping efficiency of the third volume-changing parts can be maintained at a high level.

In the aforementioned oil pump according to the aspect, the second volume-changing parts are preferably configured to be capable of changing the second volume by the change in the distance between the multiple vane-connecting parts of the outer rotor in the circumferential direction by changes in the radial slide positions of the tip ends of the vanes on the outside in the radial direction in response to the eccentricity of the inner rotor with respect to the outer rotor, the outer rotor preferably includes multiple outer rotor pieces, each of which is provided for each of the multiple vanes and includes a vane-connecting part, the multiple outer rotor pieces are preferably circumferentially arranged in a state where adjacent outer rotor pieces engage with each other so as to be capable of changing a distance therebetween in the circumferential direction, the adjacent outer rotor pieces preferably engage with each other in the circumferential direction while having engagement spaces constituting the second volume changing-parts, and the second volume of the engagement spaces is preferably changed by a change in the distance between the adjacent outer rotor pieces in the circumferential direction. According to this structure, properly utilizing the displacement of the radial slide positions of the tip ends of the vanes on the outside in the radial direction, distances between the multiple vane-connecting parts of the outer rotor in the circumferential direction can be easily changed (increased and decreased). Thus, properly utilizing the drive force of the vanes in the radial direction, the second volume changing-parts can perform the pumping function.

Furthermore, the multiple outer rotor pieces are circumferentially arranged in the state where the adjacent outer rotor pieces engage with each other so as to be capable of changing the distance therebetween in the circumferential direction, whereby properly utilizing the movement (expansion and contraction) of the adjacent outer rotor pieces away from and toward each other in the circumferential direction, the second volume changing-parts (second volume) can perform the pumping function of repeating their enlargement (increase) and shrinkage (decrease). Moreover, the second volume of the engagement spaces is changed by the change in the distance between the adjacent outer rotor pieces in the circumferential direction, whereby properly utilizing, as the second volume, the engagement spaces generated when the outer rotor pieces engage with each other, the second volume changing-parts can perform the pumping function of repeating an increase and decrease in the second volume.

In the aforementioned structure in which the second volume changing-parts can change the second volume in response to the eccentricity of the inner rotor with respect to the outer rotor, grooves or holes that allow the engagement spaces constituting the second volume-changing parts and the first volume-changing parts to communicate with each other are preferably provided. According to this structure, the first volume-changing parts having the first volume and the second volume-changing parts having the second volume are allowed to communicate with each other through the grooves or holes, and hence the oil can be suctioned into both the first volume-changing parts and the second volume-changing parts when the volume chambers are enlarged. When the volume chambers are shrunk, the oil can be discharged from both the first volume-changing parts and the second volume-changing parts.

In the aforementioned structure in which the adjacent outer rotor pieces engage with each other in the circumferential direction while having the engagement spaces constituting the second volume changing-parts, the engagement spaces constituting the second volume-changing parts each preferably include a first engagement space located on a first side between two adjacent vanes and a second engagement space located on a second side between the two adjacent vanes. According to this structure, when the generally annular outer rotor is configured by sequentially connecting the adjacent outer rotor pieces to each other, each of the outer rotor pieces can easily engage with an outer rotor piece adjacent on the first side (right side, for example) relative to itself through the first engagement space, and each of the outer rotor pieces can easily engage with an outer rotor piece adjacent on the second side (left side, for example) relative to itself through the second engagement space, for example.

The aforementioned structure in which the second volume-changing parts can change the second volume in response to the eccentricity of the inner rotor with respect to the outer rotor preferably further includes a suction port that suctions oil and a discharge port that discharges the oil, the outer rotor preferably includes multiple outer rotor pieces, each of which is provided for each of the multiple vanes and includes the vane-connecting part, and in the suction port, the second volume is preferably gradually increased by a gradual increase in the distance between the adjacent outer rotor pieces in the circumferential direction while in the discharge port, the second volume is preferably gradually decreased by a gradual decrease in the distance between the adjacent outer rotor pieces in the circumferential direction. According to this structure, the second volume of each of the second volume-changing parts can be increased or decreased in synchronization with the timing of sequentially passing through the suction port or the discharge port when the annular outer rotor is rotated, and hence the second volume-changing parts can effectively perform their pumping function.

The aforementioned oil pump according to the aspect preferably further includes a rotor-housing unit that houses the inner rotor and is movable in a first direction so as to change the eccentricity of the inner rotor, a suction port that suctions oil and a discharge port that discharges the oil, and a cam member linearly moved in a second direction orthogonal to the first direction in response to the discharge pressure of the oil from the discharge port, including a cam region provided to increase and decrease the eccentricity of the inner rotor by moving the rotor-housing unit in the first direction following linear movement in one direction of the second direction. According to this structure, a change can be easily made by increasing or decreasing the eccentricity of the inner rotor while moving the rotor-housing unit in the first direction through the cam region provided in the cam member following the linear movement of the cam member in one direction of the second direction in response to the discharge pressure of the oil. Therefore, according to the present invention, only the movement in one direction enables an increase and decrease in the eccentricity of the inner rotor, and hence it is not necessary to switch a position on which the oil pressure acts in response to the discharge pressure (the rotational speed of an internal combustion) of the oil. Consequently, it is not necessary to provide a hydraulic direction switching valve or the like, and hence the structure of the oil pump can be further simplified.

In the aforementioned structure further including the rotor-housing unit and the cam member, the cam member preferably includes a spool member linearly moved in the second direction in response to the discharge pressure of the oil, the rotor-housing unit preferably includes a cam engaging part arranged to face the cam region of the spool member, the amount of protrusion of the cam region of the spool member with respect to the cam engaging part of the rotor-housing unit preferably changes along the second direction, and the rotor-housing unit is preferably moved in the first direction in response to a change in the amount of protrusion of the cam region associated with movement of the spool member in one direction of the second direction so that the eccentricity of the inner rotor is increased or decreased. According to this structure, effectively utilizing a cam mechanism including the cam region of the spool member and the cam engaging part of the rotor-housing unit, the eccentricity of the inner rotor can be increased or decreased directly following the change in the amount of protrusion of the cam region associated with the movement of the spool member in one direction of the second direction.

In the aforementioned structure in which the cam member includes the spool member linearly moved in the second direction in response to the discharge pressure of the oil, the cam region of the spool member preferably includes a first cam region arranged to face the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a first pressure range, a second cam region engaging with the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a second pressure range larger than the first pressure range, and a third cam region engaging with the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a third pressure range larger than the second pressure range, and when the spool member is moved in one direction of the second direction so as to sequentially switch the cam region of the cam member to the first cam region, the second cam region, and the third cam region in response to an increase in the discharge pressure of the oil from the discharge port, the amount of movement of the rotor-housing unit in the first direction with respect to the rotation center of the inner rotor and the eccentricity of the inner rotor are preferably decreased in a case of the second cam region, and the amount of the movement of the rotor-housing unit in the first direction and the eccentricity of the inner rotor are preferably increased in a case of the third cam region from a state where the amount of the movement of the rotor-housing unit in the first direction with respect to the rotation center of the inner rotor and the eccentricity of the inner rotor are decreased in the case of the second cam region. According to this structure, based on the first cam region corresponding to the case where the discharge pressure of the oil from the discharge port is within the first pressure range, the cam region of the spool member is sequentially switched from the first cam region to the second cam region and from the second cam region to the third cam region along one direction of the second direction when the discharge pressure of the oil is increased from the first pressure range to the second pressure range and from the second pressure range to the third pressure range, and the eccentricity of the inner rotor can be both increased and decreased by the switching of the cam region following the movement of the spool member in one direction. Therefore, desired discharge pressure characteristics can be easily generated in the oil pump.

In the aforementioned structure in which the cam region includes the first cam region, the second cam region, and the third cam region, the first cam region is preferably formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is first eccentricity, the second cam region is preferably formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is second eccentricity smaller than the first eccentricity, and the third cam region is preferably formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is third eccentricity larger than the minimum value of the second eccentricity. According to this structure, based on the pump capacity in the case where the discharge pressure of the oil is within the first pressure range, the pump capacity in the case where the discharge pressure of the oil is within the second pressure range can be adjusted to be smaller than the pump capacity in the case where the discharge pressure of the oil is within the first pressure range, and the pump capacity in the case where the discharge pressure of the oil is within the third pressure range can be adjusted to be larger than the pump capacity in the case where the discharge pressure of the oil is within the second pressure range and smaller than the pump capacity in the case where the discharge pressure of the oil is within the first pressure range.

In this case, the second cam region is preferably provided such that the eccentricity of the inner rotor is decreased from the first eccentricity to the second eccentricity toward the third cam region, and the third cam region is preferably provided such that the eccentricity of the inner rotor is increased from the second eccentricity to the third eccentricity toward a side opposite to the second cam region. According to this structure, when the spool member is moved in one direction of the second direction, the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction can be easily decreased in the case of the second cam region. Furthermore, when the spool member is moved on one direction of the second direction, the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction can be easily increased in the case of the third cam region.

In the aforementioned structure in which the cam region includes the first cam region, the second cam region, and the third cam region, the first cam region of the spool member is preferably linearly moved to a position corresponding to the cam engaging part of the rotor-housing unit in the first pressure range so that the rotor-housing unit is linearly moved to a first eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to first eccentricity, which is maximum eccentricity, the second cam region of the spool member is preferably linearly moved to a position engaging with the cam engaging part of the rotor-housing unit in the second pressure range so that the rotor-housing unit is linearly moved to a second eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to second eccentricity smaller than the first eccentricity, and the third cam region of the spool member is preferably linearly moved to the position engaging with the cam engaging part of the rotor-housing unit in the third pressure range so that the rotor-housing unit is linearly moved to a third eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to third eccentricity larger than the minimum value of the second eccentricity. According to this structure, the rotor-housing unit can be moved to any of the first eccentricity position, the second eccentricity position, and the third eccentricity position corresponding to the first pressure range, the second pressure range, and the third pressure range, respectively, and the eccentricity of the inner rotor can be properly adjusted to the first eccentricity, the second eccentricity, and the third eccentricity. Therefore, the oil pump capable of accurately exhibiting the required discharge pressure characteristics can be obtained.

The aforementioned structure further including the rotor-housing unit and the cam member preferably further includes a first urging member that urges the rotor-housing unit toward the cam member and a second urging member that urges the cam member toward a position on the side of the discharge port. According to this structure, when the rotor-housing unit is moved in the first direction following the linear movement of the cam member in one direction of the second direction, the rotor-housing unit can be moved in the first direction while properly following the cam shape (concave-convex shape) of the cam region of the cam member by the urging force of the first urging member on the rotor-housing unit toward the cam member. Furthermore, the second urging member that urges the cam member toward a position on the side of the discharge port is provided, whereby when the discharge pressure of the oil from the discharge port is decreased, the cam member can be easily pushed back in another direction opposite to one direction of the second direction by the urging force of the second urging member. Thus, the cam member can perform a reversible operation in response to the discharge pressure of the oil.

According to the present application, the following structure is also conceivable in the aforementioned oil pump according to the aspect.

More specifically, in the aforementioned oil pump according to the aspect, an oil film is preferably formed on the outer surface of the outer rotor. According to this structure, even when the outer rotor includes the multiple vane-connecting parts and is configured to involve the change in its shape causing the change in the second volume of the second volume-changing parts resulting from the change in the distance between the adjacent vane-connecting parts in the circumferential direction, the oil film is formed on the outer surface of the outer rotor so that the annular outer rotor involving this change in its shape can be smoothly rotated in a casing of the oil pump. Furthermore, due to this oil film, the second volume of the second volume-changing parts can be smoothly changed.

In the aforementioned oil pump according to the aspect, the multiple vanes are preferably mounted on the vane-housing unit of the inner rotor so as to be capable of sliding in the radial direction without swinging in the circumferential direction. According to this structure, the vanes can appear from and disappear into the vane-housing unit while linearly (one-dimensionally) sliding along the radial direction when the oil pump operates, and hence it is not necessary to form, in the vanes, such a unique shape that the intermediate part of each of the vanes that appears from and disappears into the vane-housing unit is narrowed, for example. In other words, unlike the swinging pendulums (vanes) having the intermediate parts narrower than both ends, a factor to reduce the pumping efficiency due to the unique shape of the intermediate part can be removed. Therefore, the highly-efficient pumping function can be provided to the oil pump.

In the aforementioned oil pump in which the outer rotor includes the multiple outer rotor pieces, the outer rotor pieces each have engaging pieces engageable with each other in the circumferential direction in a state where the adjacent outer rotor pieces overlap each other in the radial direction, and the engagement spaces constituting the second volume-changing parts are configured to change the second volume by the change in a distance between the engaging pieces in the circumferential direction in response to the amount of overlap of the engaging pieces. According to this structure, the second volume of the engagement spaces can be easily increased or decreased in response to the amount of overlap of the engaging pieces overlapping each other, and hence the outer rotor (second volume-changing parts) can easily perform the pumping function.

In the aforementioned oil pump in which the cam region includes the first cam region, the second cam region, and the third cam region, the first cam region, the second cam region, and the third cam region are preferably continuously provided, and the cam engaging part of the rotor-housing unit is preferably configured to be moved in the first direction by sliding along at least the second cam region and the third cam region following the movement of the spool member. According to this structure, the rotor-housing unit can be moved in the first direction while engaging with the cam region (the second cam region and the third cam region) so as to follow the cam shape of the cam region when the spool member is moved in one direction of the second direction, and hence based on the first cam region corresponding to the case where the discharge pressure of the oil from the discharge port is within the first pressure range, the eccentricity of the inner rotor can be smoothly decreased in the case of the second cam region, and the eccentricity of the inner rotor can be smoothly increased from the decreased state in the case of the third cam region.

In the aforementioned oil pump according to the aspect, there is preferably a hysteresis error between the characteristics of the eccentricity of the inner rotor resulting from movement of the rotor-housing unit in the first direction in response to the change in the amount of protrusion of the cam region generated when the cam member is linearly moved in one direction of the second direction and the characteristics of the eccentricity of the inner rotor resulting from the movement of the rotor-housing unit in the first direction in response to the change in the amount of protrusion of the cam region generated when the cam member is linearly moved in another direction of the second direction opposite to one direction. According to this structure, even when the discharge pressure of the oil from the discharge port repeatedly fluctuates up and down at short time intervals, the characteristics of the eccentricity of the inner rotor have the hysteresis error in response to the movement direction of the cam member, and hence generation of the phenomenon (chattering phenomenon) where the linear movement of the cam member in one direction and another direction of the second direction following the frequent up-and-down fluctuation of the discharge pressure and the wiggle back-and-forth movement of the rotor-housing unit in the first direction based on this are frequently repeated can be avoided in the oil pump. Therefore, even when the discharge pressure of the oil from the discharge port repeatedly fluctuates up and down at the short time intervals, the eccentricity of the inner rotor does not vary in a fluctuating manner, and hence the oil can be stably discharged.

In the aforementioned oil pump further including the rotor-housing unit and the cam member, at least part of the oil suctioned into the suction port is supplied to the cam region of the cam member. According to this structure, when the rotor-housing unit is moved in the first direction through the cam region provided in the cam member, the oil, the pressure of which is decreased to below the discharge pressure, is easily drawn into the cam region so that a part of the rotor-housing unit coming into contact with the cam region can be smoothly moved, and hence cam operation for moving the rotor-housing unit in the first direction can be smoothly performed by the cam member. Thus, the smooth discharge pressure characteristics accurately following the discharge pressure of the oil from the discharge port can be obtained.

Effect of the Invention

According to the present invention, as hereinabove described, the oil pump capable of sufficiently increasing the net rate of discharge of the oil per unit rotation can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** An exploded perspective view showing the structure of a pump element in an oil pump according to a first embodiment of the present invention.

FIG. **2** A diagram showing the internal structure of the oil pump according to the first embodiment of the present invention.

FIG. **3** A front elevational view showing the structure of an outer rotor piece (single item) constituting the oil pump according to the first embodiment of the present invention.

FIG. **4** A top plan view showing the structure of the outer rotor piece (single item) constituting the oil pump according to the first embodiment of the present invention.

FIG. **5** A top plan view showing engagement between adjacent outer rotor pieces in an outer rotor constituting the oil pump according to the first embodiment of the present invention.

FIG. **6** A perspective view showing the engagement between the adjacent outer rotor pieces in the outer rotor constituting the oil pump according to the first embodiment of the present invention.

FIG. **7** A diagram showing the internal structure of the oil pump according to the first embodiment of the present invention.

FIG. **8** A diagram for illustrating the operation of the oil pump according to the first embodiment of the present invention.

FIG. **9** A diagram for illustrating the operation of the oil pump according to the first embodiment of the present invention.

FIG. **10** A diagram showing the internal structure of an oil pump according to a second embodiment of the present invention.

FIG. **11** A front elevational view showing the structure of an outer rotor piece (single item) constituting the oil pump according to the second embodiment of the present invention.

FIG. **12** A top plan view showing the structure of the outer rotor piece (single item) constituting the oil pump according to the second embodiment of the present invention.

FIG. **13** A diagram showing engagement between adjacent outer rotor pieces in an outer rotor constituting the oil pump according to the second embodiment of the present invention.

FIG. **14** A diagram showing the internal structure of the oil pump according to the second embodiment of the present invention.

FIG. **15** A sectional view showing the overall structure of an oil pump according to a third embodiment of the present invention.

FIG. **16** A perspective view partially showing the internal structure of a pump-housing unit of a pump body constituting the oil pump according to the third embodiment of the present invention.

FIG. **17** A perspective view showing the structure of a spool member constituting the oil pump according to the third embodiment of the present invention.

FIG. **18** A diagram for illustrating the operation of the oil pump according to the third embodiment of the present invention.

FIG. **19** A diagram for illustrating the operation of the oil pump according to the third embodiment of the present invention.

FIG. **20** A diagram for illustrating the operation of the oil pump according to the third embodiment of the present invention.

FIG. **21** A diagram for illustrating the operation of the oil pump according to the third embodiment of the present invention.

FIG. **22** A diagram showing the characteristics (engine rotational speed-discharge pressure characteristics) of the oil pump according to the third embodiment of the present invention and the characteristics (engine rotational speed-discharge pressure characteristics) of an oil pump as a comparative example to the third embodiment.

FIG. **23** A diagram for illustrating that the characteristics of the oil pump according to the third embodiment of the present invention have a hysteresis error.

FIG. **24** A sectional view showing the overall structure of an oil pump according to a fourth embodiment of the present invention.

FIG. **25** A diagram showing the characteristics (engine rotational speed-discharge pressure characteristics) of the oil pump according to the fourth embodiment of the present invention and the characteristics (engine rotational speed-discharge pressure characteristics) of the oil pump as the comparative example to the third embodiment.

FIG. **26** A top plan view showing the structure of an outer rotor piece (single item) constituting a pump element in an oil pump according to a modification of the present invention.

MODES FOR CARRYING OUT THE INVENTION

Embodiments of the present invention are hereinafter described on the basis of the drawings.

First Embodiment

The structure of an oil pump **100** according to a first embodiment of the present invention is now described with reference to FIGS. **1** to **7**. In FIGS. **1** and **2**, main components constituting the oil pump **100** are denoted by reference numerals, and in FIGS. **3** to **7**, the detailed configuration (structure) of the oil pump **100** is denoted by reference numerals.

The oil pump **100** according to the first embodiment of the present invention includes an inner rotor **10**, an outer rotor **20**, and six vanes **30** connecting the inner rotor **10** and the outer rotor **20**, as shown in FIG. **1**. The inner rotor **10**, the outer rotor **20**, and the six vanes **30** constitute a pump element **35** having a pumping function.

The oil pump **100** also includes a housing **40** made of an iron-based metal material, housing the annular outer rotor **20** such that the outer rotor **20** is rotatable along arrow Q2 and a pump body (casing) **50** made of an aluminum alloy, housing the housing **40** such that the housing **40** is movable (in a direction Y), as shown in FIG. **2**. In FIG. **1**, illustration of the housing **40** housing the outer rotor **20** and the pump body **50** (see FIG. **2**) is omitted in order to show the internal structure of the oil pump **100**. The oil pump **100** is mounted on an unshown internal combustion (engine) or the like, for example, and in this case, the oil pump **100** has a function of supplying oil (lubricating oil) **1** (see FIG. **2**) in an oil pan around pistons and to a movable part (slide part) such as a crankshaft.

As shown in FIG. **2**, the oil pump **100** includes a suction port **52** that suctions the oil **1** and a discharge port **53** that discharges the oil **1**. The suction port **52** and the discharge port **53** are formed behind (the rear side of the plane of the figure) the housing **40** in the pump body **50**. The oil pump **100** further includes an unshown cover covering the pump body **50** from the front side of the plane of the figure. Thus, six volume chambers **61** surrounded by the inner rotor **10**, the outer rotor **20**, and the six vanes **30**, respectively, are formed in the pump body **50** closed by the cover. Each of the volume chambers **61** has a volume V**1**. As described later, the volume V**1** is increased or decreased in response to changes (enlargement or shrinkage) in the shapes of the volume chambers **61** resulting from expansion and contraction (slide) of the vanes **30** during the operation of the oil pump **100**. The volume chambers **61** are examples of the "first volume-changing part" in the present invention. The volume V**1** is an example of the "first volume" in the present invention.

The structure of the pump element **35** is now described. The operation of the oil pump **100** is described later in detail.

The inner rotor **10** made of an iron-based metal material includes a shaft hole **11** in a central part serving as a rotation center R, as shown in FIGS. **1** and **2**. An unshown drive shaft is connected to the shaft hole **11** so that the inner rotor **10** is rotated in one direction (along arrow Q**2**) in a state where the position of the rotation center R is fixed. In the oil pump **100**, the crankshaft of the internal combustion (engine) is used as a drive source for the inner rotor **10**. The inner rotor **10** includes a vane-housing unit **12** provided along the outer periphery of the inner rotor **10**.

The vane-housing unit **12** includes six recess parts **12***a* extending in a radial direction from the outer periphery of the inner rotor **10** toward the shaft hole **11** (rotation center R). The term "radial direction" described here denotes a direction along a radius of rotation when the inner rotor **10** is rotated about the rotation center R. Each of the recess parts **12***a* has a prescribed depth in the radial direction, and the recess parts **12***a* are arranged at equal angular intervals (60-degree intervals) about the shaft hole **11**. The recess parts **12***a* extend in the form of a groove along a direction X from an end surface of the inner rotor **10** on one side (X2 side) to an end surface of the inner rotor **10** on another side (X**1** side). A width W (see FIG. **7**) of each of the recess parts **12***a* slidably holding the vanes **30** from an inner wall surface on one side extending in the direction X to an inner wall surface on another side opposed to the inner wall surface on one side is constant. The inner rotor **10** has a prescribed rotor width L (see FIG. **1**) along the direction X. The rotor width L is equal to the lengths (widths) of the outer rotor **20** and the housing **40** in the direction X.

The outer rotor **20** made of an aluminum alloy includes six outer rotor pieces **21**, as shown in FIG. **2**. The outer rotor pieces **21** are sequentially connected to (engage with) each other in a circumferential direction. Thus, the outer rotor **20** is configured to be rotated along arrow Q2 with respect to the housing **40** in a state where the outer rotor pieces **21** are annularly connected to each other along the inner peripheral surface **40***a* of the housing **40**.

The outer rotor pieces **21** each include a first engaging piece **21***a*, a second engaging piece **21***b*, a third engaging piece **21**c, and a fourth engaging piece **21**d, each of which is formed in an arcuate shape, as shown in FIG. **3**. The outer rotor pieces **21** each further include a base **21**e extending in an axial direction (direction X), and base parts of the first engaging piece **21**a and the fourth engaging piece **21**d on a Q**2** side, extending in the axial direction (direction X), are connected to the base **21**e from a Q**1** side. Furthermore, base parts of the second engaging piece **21**b and the third engaging piece **21**c on the Q**1** side, extending in the axial direction (direction X), are connected to the base **21**e from the Q**2** side. In this description, the Q**1** side and the Q**2** side correspond to a first side and a second side of the outer rotor pieces **21** in the circumferential direction, respectively. Therefore, each of the outer rotor pieces **21** is a unitary monolithic component in which the first engaging piece **21**a to the fourth engaging piece **21**d have such a shape that an arcuate wing is spread in the circumferential direction (along arrow Q**1** and arrow Q**2**) about the base **21**e. The base **21**e is an example of the "vane-connecting part" in the present invention.

When one outer rotor piece **21** is viewed along arrow Z**1** from above (Z**2** side) in FIG. **3**, the first engaging piece **21**a and the third engaging piece **21**c arranged diagonally to each other about the base **21**e are arranged outside (the front side of the plane of the figure) in the radial direction in the outer rotor piece **21**, as shown in FIG. **4**. On the other hand, the second engaging piece **21**b and the fourth engaging piece **21**d arranged diagonally to each other are arranged inside (the rear side of the plane of the figure) in the radial direction relative to the first engaging piece **21**a and the third engaging piece **21**c. Therefore, the first engaging piece **21**a to the fourth engaging piece **21**d are arranged alternately (staggeredly) along the radial direction as outside, inside, outside, and inside in the radial direction in this order. As shown in FIG. **2**, an outer surface **3** of each of the first engaging piece **21**a and the third engaging piece **21**c is slid in the circumferential direction (along arrow Q) through an oil film **1**a with respect to the inner peripheral surface **40**a of the housing **40**.

When the outer rotor pieces **21** in which the first engaging piece **21**a to the fourth engaging piece **21**d have a staggered structure are connected to each other, as shown in FIG. **5**, the first engaging piece **21**a of each of the outer rotor pieces **21** on the Q**2** side engages with the second engaging piece **21**b of each of the outer rotor pieces **21** on the Q**1** side so as to cover the second engaging piece **21**b from the outside (on the front side of the plane of the figure) in the radial direction. The fourth engaging piece **21**d of each of the outer rotor pieces **21** on the Q**2** side engages with the third engaging piece **21**c of each of the outer rotor pieces **21** on the Q**1** side so as to crawl into the inside (the rear side of the plane of the figure) of the third engaging piece **21**c in the radial direction. More specifically, the inner surface **2** of the first engaging piece **21**a relatively on the Q**2** side, located on the inside in the radial direction, and the outer surface **3** of the second engaging piece **21**b adjacent relatively in a direction Q**1**, located on the outside in the radial direction, come into contact (surface contact) with each other. The outer surface **3** of the fourth engaging piece **21**d relatively on the Q**2** side, located on the outside in the radial direction, and the inner surface **2** of the third engaging piece **21**c adjacent relatively in the direction Q**1**, located on the inside in the radial direction, come into contact (surface contact) with each other.

Therefore, the first engaging piece **21**a and the fourth engaging piece **21**d of the outer rotor piece **21** on the Q**2** side and the second engaging piece **21**b and the third engaging piece **21**c of the outer rotor piece **21** adjacent on the Q**1** side to this outer rotor piece **21** are alternately combined along a rotor width direction (direction X), as shown in FIGS. **5** and **6**. The inner surface **2** and the outer surface **3** of each of the first engaging piece **21**a and the fourth engaging piece **21**d on the Q**2** side and the second engaging piece **21**b and the third engaging piece **21**c on the Q**1** side sequentially repetitively engage with each other in the outer rotor pieces **21** adjacent along a direction Q. In this manner, the six outer rotor pieces **21** are annularly (circumferentially) connected to each other, whereby the outer rotor **20** (see FIG. **2**) is configured.

The first engaging piece **21**a to the fourth engaging piece **21**d each are formed in the arcuate shape, and hence an overlapping margin (engagement area) of the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q) can be increased or decreased along arrow Q**1** or arrow Q**2** in a prescribed range (a length range of each of the pieces in the circumferential direction). In FIG. **6**, the outer rotor pieces **21** adjacent to each other are viewed from a side on which the inner rotor **20** (see FIG. **2**) is arranged. Therefore, in the outer rotor **20** incorporated in the housing **40** (see FIG. **2**), engagement between the adjacent outer rotor pieces **21** is maintained while a distance (engagement area) between the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q) is increased or decreased in the prescribed range.

According to the first embodiment, engagement spaces **5** to **8** described below are formed between the outer rotor pieces **21** adjacent to each other along arrow Q.

Specifically, one engagement space **5** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the outer surface **3** of the second engaging piece **21**b by engagement between the first engaging piece **21**a of one outer rotor piece **21** on the Q**2** side and the second engaging piece **21**b of the outer rotor piece **21** adjacent on the Q**1** side, as shown in FIGS. **5** and **6**. The engagement space **5** is a space formed between the outer surface **3** of the second engaging piece **21**b and the inner peripheral surface **40**a (see FIG. **2**) of the housing **40** that faces this. The engagement space **5** is located on the Q**1** side (first side) between two adjacent vanes **30**, as shown in FIG. **7**. Simultaneously, one engagement space **6** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the inner surface **2** of the first engaging piece **21**a. The engagement space **6** is a space directly exposed to the side of the inner rotor **10** (see FIG. **2**). The engagement space **6** is located on the Q**2** side (second side) between the two adjacent vanes **30**. The engagement spaces **5** and **6** are examples of the "first engagement space" and the "second engagement space" in the present invention, respectively.

In a connection part between the base **21**e and the second engaging piece **21**b, one notch part **21**f is formed. The notch part **21**f is formed by partially notching the second engaging piece **21**b in a groove shape along a thickness direction to have a prescribed length (depth) in the axial direction (direction X) from an end of the base **21**e on one side (X**2** side). Thus, the side of the inner surface **2** of the second engaging piece **21**b communicates with the side of the outer surface **3** of the second engaging piece **21**b. Thus, according to the first embodiment, the engagement space **5** located on the side of the outer surface **3** of the outer rotor **20** and a volume chamber **61** surrounded by the inner rotor **10**, the outer rotor **20**, and the two adjacent vanes **30** communicate with each other through the notch part **21**f, as shown in FIG. **7**. The volume of the notch part **21**f is preferably as small as possible relative to the engagement space **5** in a range where the oil **1** easily flows. The notch part **21***f* is an example of the "groove part" in the present invention.

In the outer rotor **20**, another similar structure exists. As shown in FIGS. **5** and **6**, one engagement space **7** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the outer surface **3** of the fourth engaging piece **21***d* by engagement between the fourth engaging piece **21***d* of one outer rotor piece **21** on the Q**2** side and the third engaging piece **21***c* of the outer rotor piece **21** adjacent on the Q**1** side. The engagement space **7** is a space formed between the outer surface **3** of the fourth engaging piece **21***d* and the inner peripheral surface **40***a* (see FIG. **2**) of the housing **40** that faces this. The engagement space **7** is located on the Q**2** side (second side) between two adjacent vanes **30**, as shown in FIG. **7**. Simultaneously, one engagement space **8** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the inner surface **2** of the third engaging piece **21***c*. The engagement space **8** is a space directly exposed to the side of the inner rotor **10**. The engagement space **8** is located on the Q**1** side (first side) between the two adjacent vanes **30**. The engagement spaces **7** and **8** are examples of the "second engagement space" and the "first engagement space" in the present invention, respectively.

In an end in which the first engaging piece **21***a* and the fourth engaging piece **21***d* face each other in the axial direction (direction X), one notch part **21***g* extending from an end on the Q**1** side to the base **21***e* along the circumferential direction (along arrow Q) is formed. The notch part **21***g* is formed by partially notching the fourth engaging piece **21***d* in a groove shape along the thickness direction in a state where the notch part **21***g* has a prescribed width in the direction X. Thus, the side of the inner surface **2** of the first engaging piece **21***a* communicates with the side of the outer surface **3** of the fourth engaging piece **21***d*. Thus, according to the first embodiment, the engagement space **7** located on the side of the outer surface **3** of the outer rotor **20** and a volume chamber **61** (see FIG. **7**) surrounded by the inner rotor **10**, the outer rotor **20**, and the two adjacent vanes **30** communicate with each other through the notch part **21***g*, as shown in FIG. **6**. The volume of the notch part **21***g* is preferably as small as possible relative to the engagement space **7** in a range where the oil **1** easily flows. The notch part **21***g* is an example of the "groove part" in the present invention.

As can be seen in FIG. **6**, the engagement spaces **6** and **8** are arranged on the side of the inner surface **2** in the radial direction of the rotation of the outer rotor **20**, and hence the engagement spaces **6** and **8** are substantially connected to (communicate with) the volume chamber **61** (see FIG. **7**).

One volume chamber **62** having a volume V**2** is formed between the outer rotor pieces **21** engaging with each other by the aforementioned engagement spaces **5**, **6**, **7**, and **8**. More specifically, the total volume of the engagement spaces **5** to **8** corresponds to the volume V**2**. The engagement spaces **6** and **8** substantially communicate with the volume chamber **61**, but are described distinctively from the volume chamber **61** as engagement spaces, the sizes of which can be increased or decreased, formed on the side of the outer rotor **20**. The volume chamber **62** is configured such that the operations of increasing or decreasing the volumes of the engagement spaces **5** to **8** are synchronized following an increase or decrease in the overlapping margin (engagement area) of the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q) in the prescribed range. More specifically, when the adjacent outer rotor pieces **21** are displaced in a direction away from each other, the "overlapping margin" is decreased, and the volume V**2** of the engagement spaces **5** to **8** is monotonically increased. When the adjacent outer rotor pieces **21** are displaced in a direction toward each other, the "overlapping margin" is increased, and the volume V**2** of the engagement spaces **5** to **8** is monotonically decreased. The operations of increasing or decreasing the volumes of the engagement spaces **5** to **8** serve the pumping function of the outer rotor **20** described later. The volume chamber **62** is an example of the "second volume-changing part" in the present invention. The volume V**2** is an example of the "second volume" in the present invention.

As shown in FIG. **3**, the base **21***e* of each of the outer rotor pieces **21** is formed with an engaging part **21***h* having a prescribed inner diameter, formed by partially notching the inside in the radial direction in an arcuate shape (C shape). As shown in FIG. **4**, the engaging part **21***h* linearly extends from the end of the base **21***e* on one side (X**2** side) to an end of the base **21***e* on another side (X**1** side) along the axial direction, and the engaging part **21***h* passes through the base **21***e* in the axial direction (direction X). More specifically, the length of the engaging part **21***h* in the direction X is equal to the width (the rotor width L of the inner rotor **10**) of each of the vanes **30**. The engaging portion **21***h* is an example of the "vane-connecting part" in the present invention.

As shown in FIGS. **3** and **4**, on the outer surface **3** of each of the outer rotor pieces **21** located on the outside in the radial direction, a side end **21***j* of the first engaging piece **21***a* opposite (Q**1** side) to the base **21***e*, a side end **21***k* of the third engaging piece **21***c* opposite (Q**2** side) to the base **21***e*, and a side end **21***m* of the base **21***e* on the Q**2** side each have a slightly tapered shape by reducing a thickness in the radial direction. Thus, when the outer rotor **20** in which the six outer rotor pieces **21** are combined rotates along the inner peripheral surface **40***a* of the housing **40**, the oil **1** (see FIG. **2**) is easily drawn into a small gap between the outer surface **20***a* of the outer rotor **20** and the inner peripheral surface **40***a* of the housing **40**. Therefore, according to the first embodiment, the outer rotor **20** is configured to rotate in the housing **40** in a state where the thin oil film **1***a* is formed on the outer surface **20***a* of the outer rotor **20**, as shown in FIGS. **2** and **7**.

The vanes **30** made of an aluminum alloy each have a base **31** and a tip end **32**, as shown in FIG. **7**. The base **31** has a slightly narrow part formed by reducing a thickness T on the side of the tip end **32**, and the tip end **32** is integrally connected to a tip of this narrow part. The base **31** has a base part **31***a*. The vanes **30** are configured to be inserted into the recess parts **12***a* (vane-housing unit **12**) of the inner rotor **10** from the side of the base part **31***a*. The base **31** is an example of the "part housed in the vane-housing unit" in the present invention.

According to the first embodiment, the thickness T of the base **31** is constant along the radial direction (the movement direction of the vanes **30**). The width W of one recess part **12***a* is slightly larger than the thickness T of the base **31**, and the outer surface of the base **31** extending in the direction X is smoothly slid (slidingly moved) with respect to the inner surface of the recess part **12***a* extending in the direction X along the radial direction of rotation. More specifically, the multiple vanes **30** are arranged in the recess parts **12***a* of the vane-housing unit **12** of the inner rotor **10** so as not to swing in the circumferential direction (along arrow Q), which is the rotation direction of the inner rotor **10** but so as to be capable of sliding along with the protrusion of tip ends **32** from the recess parts **12***a* to the outside in the radial direction and the retraction of base parts **31***a* opposite thereto toward the recess parts **12***a* on the inside in the radial direction.

According to the first embodiment, one volume chamber **63** having a volume V**3** is formed in the vane-housing unit **12** of the inner rotor **10** by the recess part **12***a* and the base part **31***a* of the vane **30**. The vane **30** is slid to freely appear from and disappear into the recess part **12***a*, whereby the volume V**3** of the volume chamber **63** is increased or decreased. In other words, the volume V**3** is increased when the vane **30** (tip end **32**) jumps out of the recess part **12***a*, and the volume V**3** is decreased when the vane **30** (base part **31***a*) is drawn into the recess part **12***a*. The volume chamber **63** is an example of the "third volume-changing part" in the present invention. The volume V**3** is an example of the "third volume" in the present invention.

The tip end **32** of the vane **30** is rounded, and the tip end **32** is configured to be fitted into the engaging part **21***h* formed in the base **21***e* of the outer rotor piece **21**. The cross-sectional area of the engaging part **21***h* is slightly larger than the cross-sectional area of the tip end **32**, and the outer peripheral surface of the tip end **32** is connected to (engages with) the inner peripheral surface of the engaging part **21***h* with a slight airspace. Thus, the vane **30** is configured to be capable of sliding with respect to the recess part **12***a* of the inner rotor **10** in the radial direction regardless of a connection angle between the vane **30** and the outer rotor piece **21**. Furthermore, the outer rotor **20** is configured to be rotatable in the housing **40** while maintaining an annular shape as a whole regardless of the connection angle between the vane **30** and the outer rotor piece **21** also on the side of the outer rotor pieces **21** annularly connected to each other.

Inside the inner rotor **10**, a communication passage **13** (shown by a broken line in FIG. **2**) configured to allow the volume chamber **63** formed by the recess part **12***a* and the base part **31***a* of the vane **30** and the volume chamber **61** surrounded by the inner rotor **10**, the outer rotor **20**, and the two adjacent vanes **30** to communicate with each other is formed. Thus, according to the first embodiment, one volume chamber **61** located between the adjacent vanes **30**, the volume chamber **62** formed between the outer rotor pieces **21** engaging with each other in the circumferential direction (along arrow Q) in this part, and the volume chamber **63** in the vicinity of the volume chamber **61** are configured to communicate with each other. More specifically, six volume chambers, each of which has a set of these volume chambers **61** to **63**, are formed in a state where the volume chambers are zoned around the inner rotor **10**.

The inner rotor **10**, the outer rotor **20**, and the vanes **30** constituting the pump element **35** (see FIG. **1**) are configured as described above, whereby each component is incorporated in the oil pump **100**, as described below. More specifically, in a state where both the inner rotor **10** and the outer rotor **20** in which the six outer rotor pieces **21** are annularly connected to each other are arranged in the housing **40**, the base **31** of each of the vanes **30** is slidingly inserted into the recess part **12***a* (vane-housing unit **12**) of the inner rotor **10** along the direction X while the tip end **32** of each of the vanes **30** is fitted into the engaging part **21***h* of each of the outer rotor pieces **21** along the direction X, as shown in FIG. **2**. Furthermore, the six vanes **30** are fitted similarly so that the inner rotor **10** and the outer rotor **20** are connected to each other through the vanes **30**. Then, the unshown cover covers the pump body **50** to close the same. When the inner rotor **10** is rotated along arrow Q**2** by the drive source (crankshaft), the outer rotor **20** is also rotated along the same arrow Q**2** as the inner rotor **10** through the six vanes **30**.

FIG. **2** shows a state where the rotation center R of the inner rotor **10** and the rotation center U of the outer rotor **20** completely coincide with each other. In this case, the tip end **32** of each of the vanes **30** protrudes from the recess part **12***a* (vane-housing unit **12**) toward the outer rotor piece **21** by the same amount. Therefore, even when the inner rotor **10** is rotated, each of the vanes **30** is rotationally moved without changing the amount of protrusion and only allows the outer rotor **20** to be rotated in an accompanying manner, and hence the oil pump **100** does not perform the pumping function described later.

The housing **40** holding the outer rotor **20** is moved by a prescribed amount in the direction Y (along arrow Y**1** or Y**2**). Thus, the rotation center U of the outer rotor **20** is eccentric in a transverse direction (along arrow Y**1** or Y**2**) relative to the rotation center R of the inner rotor **10**. In this case, the tip end **32** of each of the vanes **30** protrudes from the recess part **12***a* (vane-housing unit **12**) toward the outer rotor piece **21** by an amount in response to eccentricity in each rotational position along arrow Q**2**, as shown in FIG. **7**. Therefore, each of the vanes **30** is rotationally moved while appearing from and disappearing into the recess part **12***a* along with the rotation of the inner rotor **10** and allows the outer rotor **20** to be rotated in an accompanying manner. Thus, the oil pump **100** is configured to operate with the pumping function.

The operation of the oil pump **100** according to the first embodiment is now described with reference to FIGS. **2** and **6** to **9**.

When the inner rotor **10** is first rotated along arrow Q**2**, the outer rotor **20** is also rotated through the six vanes **30** along the same arrow Q**2** as the inner rotor **10**, as shown in FIG. **2**. Then, the housing **40** holding the outer rotor **20** is moved along arrow Y**1** on the basis of prescribed control operation, as shown in FIG. **8**, whereby the rotation center U of the outer rotor **20** is eccentric in the transverse direction (direction Y**1**) with respect to the rotation center R of the inner rotor **10**.

According to the first embodiment, when the outer rotor **20** is rotated along arrow Q**2** with prescribed eccentricity with respect to the inner rotor **10**, the oil pump **100** operates such that the volume chambers **61**, **62**, and **63** serve the pumping function while changing their shapes (volumes) in response to this eccentricity. More specifically, the oil pump **100** performs the pumping function by changing (increasing or decreasing) the volume V**1** of the volume chamber **61**, the volume V**2** of the volume chamber **62**, and the volume V**3** of the volume chamber **63** in response to the eccentricity of the outer rotor **20** with respect to the inner rotor **10**.

The volume V**1** of the volume chamber **61**, the volume V**2** of the volume chamber **62**, and the volume V**3** of the volume chamber **63** are now individually described. The radial slide position of the tip end **32** (see FIG. **7**) of the vane **30** located on the outside in the radial direction is changed in response to the eccentricity of the outer rotor **20** with respect to the inner rotor **10**, following the rotational movement of the outer rotor **20**, whereby the volume chamber **61** repetitively operates to increase or decrease its volume V**1**. Specifically, when each volume chamber **61** sequentially passes through the vicinity of the suction port **52** (see FIG. **8**) along arrow Q**2** in the pump body **50**, the vane **30** gradually increases the amount of protrusion of the tip end **32** (see FIG. **7**) from the recess part **12***a* (see FIG. **7**) along the radial direction, as shown in FIGS. **8** and **9**. Due to the protrusion of the tip end

32, a distance in the circumferential direction (along arrow Q) between the adjacent outer rotor pieces 21 surrounding one volume chamber 61 is gradually increased. Thus, the volume V1 of the volume chamber 61 is gradually increased. When each volume chamber 61 sequentially passes through the vicinity of the discharge port 53 (see FIG. 8) along arrow Q2 in the pump body 50, on the other hand, the vane 30 gradually increases the amount of insertion of the base part 31*a* (see FIG. 7) into the recess part 12*a* (see FIG. 7) along the radial direction. Due to the insertion of the base part 31*a*, the distance in the circumferential direction (along arrow Q) between the adjacent outer rotor pieces 21 surrounding one volume chamber 61 is gradually decreased. Thus, the volume V1 of the volume chamber 61 is gradually decreased.

The radial slide position of the tip end 32 of the vane 30 located on the outside in the radial direction is changed in response to the eccentricity of the outer rotor 20 with respect to the inner rotor 10, following the rotational movement of the outer rotor 20, whereby the volume chamber 62 repetitively operates to increase or decrease its volume V2. Specifically, when each volume chamber 62 sequentially passes through the vicinity of the suction port 52 (see FIG. 8) along arrow Q2, the amount of protrusion of the vane 30 is increased, and the adjacent outer rotor pieces 21 are displaced in the direction away from each other so that the distance between the outer rotor pieces 21 in the circumferential direction (along arrow Q) is gradually increased. Thus, the volume V2 of the volume chamber 62 including the engagement spaces 5 to 8 is gradually increased. When each volume chamber 62 sequentially passes through the vicinity of the discharge port 53 along arrow Q2, on the other hand, the amount of insertion of the vane 30 is increased, and the adjacent outer rotor pieces 21 are displaced in the direction toward each other so that the distance in the circumferential direction (along arrow Q) between the outer rotor pieces 21 is gradually decreased. Thus, the volume V2 of the volume chamber 62 including the engagement spaces 5 to 8 is gradually decreased.

The multiple vanes 30 are slid in the radial direction in response to the eccentricity of the outer rotor 20 with respect to the inner rotor 10, whereby the volume chamber 63 repetitively operates to increase or decrease its volume V3 in the vane-housing unit 12 of the inner rotor 10. Specifically, when each volume chamber 63 sequentially passes through the vicinity of the suction port 52 (see FIG. 8) along arrow Q2, the amount of protrusion of the vane 30 is increased, and the volume V3 of the volume chamber 63 is gradually increased. When each volume chamber 63 sequentially passes through the vicinity of the discharge port 53 along arrow Q2, on the other hand, the amount of insertion of the vane 30 is increased, and the volume V3 of the volume chamber 63 is gradually decreased. FIG. 9 shows a state where the inner rotor 10 and the outer rotor 20 are rotated by about 30 degrees along arrow Q2 relative to FIG. 8.

In the oil pump 100, one volume chamber 61 located between the adjacent vanes 30, the volume chamber 62 (engagement spaces 5 to 8) formed between the outer rotor pieces 21 engaging with each other in the circumferential direction in this part, and the volume chamber 63 in the vicinity of the volume chamber 61 communicate with each other through the aforementioned notch part 21*f* (see FIG. 6), notch part 21*g* (see FIG. 6), and communication passage 13 (see FIG. 7), and enlargement and shrinkage thereof are synchronized. Thus, when passing through the vicinity of the suction port 52, a set of the volume chambers 61 to 63 in terms of a flow passage suctions the oil 1 while increasing their volume V1, volume V2, and volume V3. Then, when passing through the vicinity of the discharge port 53, a set of the volume chambers 61 to 63 in terms of a flow passage discharges the oil 1 while decreasing their volume V1, volume V2, and volume V3. Pumping resulting from the enlargement and shrinkage of the volume chambers 61 to 63 volumetrically integrated is implemented once per rotation of the inner rotor 10.

The eccentricity of the outer rotor 20 with respect to the inner rotor 10 is adjusted to arbitrary magnitude according to the movement position of the housing 40 (see FIG. 2). More specifically, when the eccentricity is relatively small, a pumping volume resulting from the enlargement and shrinkage of the volume chambers 61 to 63 volumetrically integrated is relatively small, and the rate of discharge of the oil 1 is relatively small. When the eccentricity is relatively large, the pumping volume resulting from the enlargement and shrinkage of the volume chambers 61 to 63 volumetrically integrated is relatively large, and the rate of discharge of the oil 1 is relatively large.

In the oil pump 100, a series of changes from the volume decreased state of a set of volume chambers 61 to 63 to the volume increased state of a set of volume chambers 61 to 63 and from the volume increased state of a set of volume chambers 61 to 63 to the volume decreased state of a set of volume chambers 61 to 63 in one rotation are sequentially made along with 60 degree phase shifting for each set of volume chambers. Thus, continuous pumping including suction of the oil 1 from the suction port 52 into a pump main body and discharge of the oil 1 from the discharge port 53 is implemented. The drive force of the unshown drive source rotates the inner rotor 10, and rotates the outer rotor 20 annularly connected outside the inner rotor 10 through the vanes 30, following the rotation of the inner rotor 10. At this time, the six outer rotor pieces 21 periodically change their engagement states so that pumping is generated in the outer rotor 20 (volume chamber 62). Furthermore, the drive force of the drive source slidingly (back and forth) moves the vanes 30 on the basis of the eccentricity of the outer rotor 20 with respect to the inner rotor 10 when rotating the inner rotor 10 and the outer rotor 20. At this time, in addition to moving the vanes 30 back and forth, pumping resulting from enlargement and shrinkage of volume chambers 63 is generated also in the recess parts 12*a* of the vane-housing unit 12.

Thus, in the oil pump 100, all the deformation movement of movable parts (space parts: volume chambers 61 to 63) existing in the housing 40, deformed along with the rotation of the inner rotor 10 is converted to pumping. At this time, the vanes 30 each having the unnarrowed base 31 and a contact thickness T are used, and hence no minus factor (wasted work) to increase the volume V1 inversely to the volume chamber 63 is generated in the volume chamber 61 during a decrease in the volume V3 of the volume chamber 63, and synchronous changes in the volumes of the volume chambers 61 to 63 effectively work on the pumping of the entire oil pump 100. As described above, the drive force of the drive source input into the inner roto 10 is utilized for the deformation movement of the movable parts (volume chambers 61 to 63). Therefore, in the oil pump 100, a mechanism in which the volume chambers 61 to 63 operate together contributes to the maximum possible conversion of the drive force of the drive source to pumping and the discharge of the oil 1. Particularly, the deformation movement of not only the volume chambers 61 but also the volume chambers 62 and 63 is incorporated in pumping, and hence the volume V2 of the volume chamber 62 and the volume V3 of the volume chamber 63 are effectively added to the volume V1 of the volume chamber **61**. This means that a net rate of discharge of the oil **1** per unit rotation is increased. The oil pump **100** is configured in the aforementioned manner.

According to the first embodiment, the following effects can be obtained.

More specifically, according to the first embodiment, as hereinabove described, the oil pump **100** includes the inner rotor **10** that includes the vane-housing unit **12** (six recess parts **12***a*) housing the six vanes **30** so as to be capable of sliding in the radial direction, the outer rotor **20** that includes six bases **21***e* connecting respective tip ends **32** of the six vanes **30** on the outside in the radial direction, the volume chambers **61**, the volume V**1** of which is changed in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **20**, thereby providing the pumping function, and the volume chambers **62**, which are provided in the outer rotor **20**, and the volume V**2** of which is changed by the change in the distance between the adjacent bases **21***e* in the circumferential direction in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **20**, thereby providing the pumping function. Thus, in addition to the highly-efficient pumping of the volume chambers **61** partitioned by the vanes **30**, the pumping of the volume chambers **62** newly provided in the outer rotor **20** can be effectively utilized. Therefore, the net rate of discharge of the oil **1** per unit rotation in the oil pump **100** can be sufficiently increased. Consequently, the pumping efficiency of the oil pump **100** can be improved.

According to the first embodiment, the pumping of the volume chambers **62** on the side of the outer rotor **20** is added to the volume chambers **61** efficiently ensuring the rate of discharge of the oil **1**, and hence the rate of discharge of the oil **1** can be efficiently increased. When compared at the same rate of discharge, therefore, the oil pump **100** can be reduced in size by reducing the rotor width L (see FIG. **1**), and hence the mountability of the oil pump **100** to the internal combustion (engine) or the like can be improved. Furthermore, the oil pump **100** is reduced in size so that a mechanical loss during driving of the oil pump **100** can be reduced, and hence the load of the drive source driving the oil pump **100** is reduced so that the energy can be saved.

According to the first embodiment, the oil pump **100** further includes the volume chambers **63**, the volume V**3** of which in the vane-housing unit **12** of the inner rotor **10** is changed by the slide of the multiple vanes **30** in the radial direction in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **20**, thereby providing the pumping function. Thus, the oil pump **100** can be configured to incorporate the change in the volume of the volume chambers **63** in the vane-housing unit **12** by the linear slide of the vanes **30** in the radial direction with respect to the vane-housing unit **12** into the pumping including the suction and discharge of the oil **1** without ignoring the change in the volume of the volume chambers **63** in addition to the pumping of the volume chambers **61** and the volume chambers **62**, and hence the pumping of the volume chambers **63** is effectively added so that the rate of discharge of the oil **1** per unit rotation that the oil pump **100** has can be further increased. Consequently, the oil pump **100** can be further reduced in size. Furthermore, the vanes **30** linearly sliding in the radial direction are used, and hence it is not necessary to narrow an intermediate part of each of the vanes **30** that appears from and disappears into the vane-housing unit **12** (recess part **12***a*). Therefore, no minus factor (wasted work) to newly increase the volume (newly form volume chambers) in parts on the side of the volume chambers **61** in the vicinity of the volume chambers **63** is generated during a decrease change in the volume V**3** of the volume chambers **63**, and hence the changes in the volumes of the volume chambers **61** to **63** can effectively work on the pumping of the entire oil pump **100**.

According to the first embodiment, the oil pump **100** further includes the suction port **52** that suctions the oil **1** and the discharge port **53** that discharges the oil **1**. Furthermore, the oil pump **100** is configured to gradually increase, in the suction port **52**, the volume V**3** in the vane-housing unit **12** of the inner rotor **10** by the gradual slide of the vanes **30**, housed in the vane-housing unit **12**, to the outside in the radial direction and to gradually decrease, in the discharge port **53**, the volume V**3** in the vane-housing unit **12** of the inner rotor **10** by the gradual slide of the vanes **30**, housed in the vane-housing unit **12**, to the inside in the radial direction. Thus, the change in the volume V**3** generated by repeating appearance (increase) from and disappearance (decrease) into the vane-housing unit **12** (recess parts **12***a*) along with back-and-forth linear movement of the vanes **30** to the outside and the inside in the radial direction can be easily utilized as pumping. At this time, the drive force of the oil pump **100** (the drive force of the inner rotor **10**) can be converted to not only the change in the volume (volume V**1**) of the volume chambers **61** and the change in the volume (volume V**2**) of the volume chambers **62** following the slide of the vanes **30** but also the change in the volume (volume V**3**) of the volume chambers **63** following the slide of the vanes **30**, and hence the mechanical efficiency of the oil pump **100** can be improved without wasting the drive force.

According to the first embodiment, the thickness T of each of the bases **31** of the vanes **30** housed in the vane-housing unit **12** is constant. Thus, the vanes **30** each including the base **31** housed in the vane-housing unit **12**, the thickness T of which is constant, are used, whereby the vanes **30** can stably slide in the radial direction without backlash in the vane-housing unit **12**. Furthermore, no backlash of the vanes **30** is generated during back-and-forth movement, and hence the airtightness can be improved when the volume chambers **63** repeat their enlargement (increase) and shrinkage (decrease). Thus, the pumping efficiency of the volume chambers **63** can be maintained at a high level.

According to the first embodiment, the volume chambers **62** are configured to be capable of changing the volume V**2** of the volume chambers **62** by the changes in the distances between the multiple bases **21***e* of the outer rotor **20** in the circumferential direction by the change in the radial slide positions of the tip ends **32** of the vanes **30** on the outside in the radial direction in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **20**. Thus, properly utilizing the displacement of the radial slide positions of the tip ends **32** of the vanes **30** on the outside in the radial direction, the distances between the multiple bases **21***e* of the outer rotor **20** in the circumferential direction can be easily changed (increased and decreased). Thus, properly utilizing the drive force of the vanes **30** in the radial direction, the volume chambers **62** can perform the pumping function.

According to the first embodiment, the outer rotor **20** includes the multiple outer rotor pieces **21**, each of which is provided for each of the multiple vanes **30**, each including the base **21***e*. Furthermore, the outer rotor **20** is configured such that the multiple outer rotor pieces **21** are circumferentially arranged in a state where the adjacent outer rotor pieces **21** engage with each other so as to be capable of changing the distance therebetween in the circumferential direction (along arrow Q). Thus, properly utilizing the movement (expansion and contraction) of the adjacent outer rotor pieces **21** away from and toward each other in the circumferential direction (along arrow Q), the volume chambers **62** can perform the pumping function of repeating their enlargement and shrinkage.

According to the first embodiment, the adjacent outer rotor pieces **21** engage with each other in the circumferential direction (along arrow Q) while having the engagement spaces **5** to **8** constituting the volume chamber **62**, and the oil pump **100** is configured to change the volume V**2** of the engagement spaces **5** to **8** by the change in the distance between the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q). Thus, properly utilizing, as the volume V**2**, the engagement spaces **5** to **8** generated when the outer rotor pieces **21** engage with each other, the volume chambers **62** can perform the pumping function of repeating an increase and decrease in the volume V**2**.

According to the first embodiment, the outer rotor pieces **21** each have the first engaging piece **21***a* to the fourth engaging piece **21***d* engageable with each other in the circumferential direction in a state where the adjacent outer rotor pieces **21** overlap each other in the radial direction. Furthermore, the outer rotor **20** is configured to change the volume V**2** obtained by summing the engagement spaces **5** to **8** by the change in the distance between the engagement spaces **5** and **6** partially constituting the volume chamber **62** in the circumferential direction in response to the amount of overlap of the first engaging piece **21***a* and the second engaging piece **21***b* and the change in the distance between the engagement spaces **7** and **8** partially constituting the volume chamber **62** in the circumferential direction in response to the amount of overlap of the third engaging piece **21***c* and the fourth engaging piece **21***d*. Thus, the volume V**2** of the engagement spaces **5** to **8** can be easily increased or decreased in response to the amounts of overlap of the first engaging piece **21***a* to the fourth engaging piece **21***d* overlapping each other, and hence the outer rotor **20** (volume chambers **62**) can easily perform the pumping function.

According to the first embodiment, each of the outer rotor pieces **21** is provided with the notch part **21***f* that allows the engagement space **5** constituting the volume chamber **62** and the volume chamber **61** to communicate with each other and the notch part **21***g* that allows the engagement space **7** constituting the volume chamber **62** and the volume chamber **61** to communicate with each other. Thus, the volume chamber **61** having the volume V**1** and the volume chamber **62** having the volume V**2** are allowed to communicate with each other through the notch part **21***f* and the notch part **21***g*, and hence the oil **1** can be suctioned into both the volume chamber **61** and the volume chamber **62** when the volume chambers are enlarged. When the volume chambers are shrunk, the oil **1** can be discharged from both the volume chamber **61** and the volume chamber **62**.

According to the first embodiment, the outer rotor **20** is configured such that a set of the engagement spaces **5** to **8** includes the engagement spaces **5** and **8** located on the first side (the Q**1** side in FIG. **5**) between the two adjacent vanes **30** and the engagement spaces **6** and **7** located on the second side (the Q**2** side in FIG. **5**) between the two adjacent vanes **30**. Thus, in the case where the generally annular (circumferential) outer rotor **20** is configured by sequentially connecting the adjacent outer rotor pieces **21** to each other, each of the outer rotor pieces **21** can easily engage with an outer rotor piece **21** adjacent on the first side (Q**1** side) relative to itself through the engagement spaces **5** and **8**, and each of the outer rotor pieces **21** can easily engage with an outer rotor piece **21** adjacent on the second side (Q**2** side) relative to itself through the engagement spaces **6** and **7**.

According to the first embodiment, the outer rotor **20** is configured to gradually increase the volume V**2** by a gradual increase in the distance between the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q) in the suction port **52** and to gradually decrease the volume V**2** by a gradual decrease in the distance between the adjacent outer rotor pieces **21** in the circumferential direction (along arrow Q) in the discharge port **53**. Thus, the volume V**2** of each of the volume chambers **62** can be increased or decreased in synchronization with the timing of sequentially passing through the suction port **52** or the discharge port **53** when the annular outer rotor **20** is rotated, and hence the volume chambers **62** can effectively perform their pumping function.

According to the first embodiment, the oil film **1***a* is formed on the outer surface **20***a* of the outer rotor **20**. Thus, even when the outer rotor **20** includes the multiple bases **21***e* and is configured to involve the change in its shape causing the change in the volume V**2** of the volume chambers **62** resulting from the change in the distance between the adjacent bases **21***e* in the circumferential direction, the oil film **1***a* is formed on the outer surface **20***a* of the outer rotor **20** so that the annular outer rotor **20** involving this change in its shape can be smoothly rotated in the housing **40** of the oil pump **100**. Furthermore, due to this oil film **1***a*, the volume V**2** of the volume chambers **62** can be smoothly changed.

According to the first embodiment, the multiple vanes **30** are mounted on the recess parts **12***a* of the vane-housing unit **12** of the inner rotor **10** so as to be capable of sliding in the radial direction without swinging in the circumferential direction (along arrow Q). Thus, the vanes **30** can appear from and disappear into the vane-housing unit **12** (recess parts **12***a*) while linearly (one-dimensionally) sliding along the radial direction when the oil pump **100** operates, and hence it is not necessary to form, in the vanes **30**, such a unique shape that the bases **31** of the vanes **30** appearing from and disappearing into the vane-housing unit **12** are partially narrowed. Thus, unlike the structure of vanes having intermediate parts narrower than both ends (tip ends and base parts) and swinging, a factor to reduce the pumping efficiency can be removed by using the vanes **30** each having the unnarrowed base **31** and the contact thickness T. More specifically, the highly-efficient pumping function can be provided to the volume chambers **61**.

Second Embodiment

A second embodiment is now described with reference to FIGS. **2** and **10** to **14**. In this second embodiment, an example of configuring an annular outer rotor **220** by combining outer rotor pieces **221** having shapes different from those of the outer rotor pieces **21** of the outer rotor **20** (see FIG. **2**) used in the aforementioned first embodiment is described. In FIG. **10**, main components constituting an oil pump **200** are denoted by reference numerals, and in FIGS. **11** to **14**, the detailed configuration (structure) of the oil pump **200** is denoted by reference numerals. In the figures, the same reference numerals as those in the aforementioned first embodiment are assigned to and show structures similar to those of the first embodiment.

The oil pump **200** according to the second embodiment of the present invention includes an inner rotor **10**, the outer rotor **220**, and six vanes **30** constituting a pump element **235**, as shown in FIG. **10**. In a pump body **50**, six volume chambers **261** surrounded by the inner rotor **10**, the outer rotor **220**, and the six vanes **30** are formed. The volume V**1** of each of the volume chambers **261** is increased or decreased in response to enlargement or shrinkage of the volume chambers **261** resulting from expansion and contraction (slide) of the vanes **30** during the operation of the oil pump **200**. The volume chambers **261** are examples of the "first volume-changing part" in the present invention.

According to the second embodiment, the outer rotor **220** includes six outer rotor pieces **221** configured to be capable of being sequentially connected to (engage with) each other in a circumferential direction. Thus, the outer rotor **220** is configured to be rotated along arrow Q**2** with respect to a housing **40** in a state where the outer rotor pieces **221** are annularly connected to each other in the housing **40**.

As shown in FIG. **11**, the outer rotor pieces **221** each include a first engaging piece **221***a*, a second engaging piece **221***b*, and a third engaging piece **221***c*, each of which is formed in an arcuate shape. The outer rotor pieces **221** each further include a base **221***e* extending in an axial direction (direction X), and base parts of the first engaging piece **221***a* and the second engaging piece **221***b* on a Q**2** side, extending in the axial direction (direction X), are connected to the base **221***e* from a Q**1** side. Furthermore, a base part of the third engaging piece **221***c* on the Q**1** side, extending in the axial direction (direction X), is connected to the base **221***e* from the Q**2** side. Therefore, each of the outer rotor pieces **221** is a unitary monolithic component in which the first engaging piece **221***a* and the second engaging piece **221***b* on the Q**1** side relative to the base **221***e* and the third engaging piece **221***c* on the Q**2** side relative to the base **221***e* have such a shape that an arcuate wing is spread. Furthermore, the outer rotor pieces **221** each have a uniform cross-sectional shape from an end on an X**2** side to an end on an X**1** side, except for a notch part **221***f* and a notch part **221***g* described later, as shown in FIG. **12**. The base **221***e* is an example of the "vane-connecting part" in the present invention.

When the outer rotor pieces **221** are connected to each other, as shown in FIG. **13**, the first engaging piece **221***a* and the second engaging piece **221***b* of an outer rotor piece **221** on the Q**2** side engage with the third engaging piece **221***c* of an outer rotor piece **221** adjacent on the Q**1** side so as to hold the third engaging piece **221***c* from the outside and inside in a radial direction. An engaging state where the third engaging piece **221***c* of the outer rotor piece **221** on the Q**2** side (second side) is held between the first engaging piece **221***a* and the second engaging piece **221***b* of the outer rotor piece **221** on the Q**1** side (first side) is sequentially repeated in the outer rotor pieces **221** adjacent along a direction Q. In this manner, the six outer rotor pieces **221** are annularly (circumferentially) connected to each other, whereby the outer rotor **220** (see FIG. **10**) is configured.

As shown in FIG. **13**, an overlapping margin (engagement area) of the adjacent outer rotor pieces **221** in the circumferential direction (along arrow Q) can be increased or decreased along arrow Q in a prescribed range (a length range of each of the pieces in the circumferential direction). Therefore, in the outer rotor **220** incorporated in the housing **40** (see FIG. **10**), engagement between the adjacent outer rotor pieces **221** is maintained while a distance (engagement area) between the adjacent outer rotor pieces **221** in the circumferential direction (along arrow Q) is increased or decreased in the prescribed range.

According to the second embodiment, engagement spaces **201** to **203** described below are formed between the outer rotor pieces **21** adjacent to each other along arrow Q.

Specifically, one engagement space **201** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the outer surface **3** of the third engaging piece **221***c* by engagement between the first engaging piece **221***a* and the second engaging piece **221***b* of one outer rotor piece **221** on the Q**2** side and the third engaging piece **221***c* of the outer rotor piece **221** adjacent on the Q**1** side, as shown in FIG. **13**. This engagement space **201** is a space formed between the outer surface **3** of the third engaging piece **221***c* and the inner peripheral surface **40***a* (see FIG. **10**) of the housing **40** that faces this. Simultaneously, one engagement space **202** that enables increase and decrease (expansion and contraction) in volume is formed on the side of the inner surface **2** of the third engaging piece **221***c*. This engagement space **202** is a space directly exposed to the side of the inner rotor **10** (see FIG. **10**). Furthermore, one engagement space **203** that enables increase and decrease (expansion and contraction) in volume is formed in a part into which the third engaging piece **221***c* is inserted and where the first engaging piece **221***a* and the second engaging piece **221***b* face each other. The engagement spaces **201** and **202** are located on the Q**1** side (first side) between the two adjacent vanes **30**, as shown in FIG. **14**. The engagement space **203** is located on the Q**2** side (second side) between the two adjacent vanes **30**. The engagement spaces **201** and **202** are examples of the "first engagement space" in the present invention. The engagement space **203** is an example of the "second engagement space" in the present invention.

As shown in FIGS. **11** and **12**, in a connection part between the base **221***e* and the second engaging piece **221***b*, one notch part **221***f* is formed. The notch part **221***f* is formed by partially notching the second engaging piece **221***b* in a groove shape along a thickness direction to have a prescribed length (depth) in the axial direction (direction X) from an end of the base **221***e* on one side (X**2** side). Thus, the side of the inner surface **2** of the second engaging piece **221***b* communicates with the side of the outer surface **3** of the second engaging piece **221***b*. Thus, according to the second embodiment, the engagement space **203** located between the first engaging piece **221***a* and the second engaging piece **221***b* and a volume chamber **261** surrounded by the inner rotor **10**, the outer rotor **220**, and the two adjacent vanes **30** communicate with each other through the notch part **221***f*. The volume of the notch part **221***f* is preferably as small as possible relative to the engagement space **203** in a range where oil **1** easily flows. The notch part **221***f* is an example of the "groove part" in the present invention.

Furthermore, in a connection part between the base **221***e* and the third engaging piece **221***c*, one notch part **221***g* is formed. The notch part **221***g* is formed by partially notching the third engaging piece **221***c* in a groove shape along the thickness direction to have a prescribed length (depth) in the axial direction (direction X) from the end of the base **221***e* on one side (X**2** side). Thus, the side of the inner surface **2** of the third engaging piece **221***c* communicates with the side of the outer surface **3** of the third engaging piece **221***c*. Thus, according to the second embodiment, the engagement space **201** located on the side of the outer surface **3** of the third engaging piece **221***c* and the engagement space **202** (volume chamber **261**) located on the side of the inner surface **2** of the third engaging piece **221***c* communicate with each other through the notch part **221***g*. The volume of the notch part **221***g* is preferably as small as possible relative to the engagement space **201** in a range where the oil **1** easily flows. The notch part **221***g* is an example of the "groove part" in the present invention.

As shown in FIG. **13**, one volume chamber **262** having a volume V**2** is formed between the outer rotor pieces **221** engaging with each other by the aforementioned engagement spaces **201**, **202**, and **203**. More specifically, the total volume of the engagement spaces **201** to **203** corresponds to the volume V**2**. The engagement space **202** substantially communicates with the volume chamber **261**, but is described distinctively from the volume chamber **261** as an engagement space, the size of which can be increased or decreased, formed on the side of the outer rotor **220**. The volume chamber **262** is configured such that the operations of increasing or decreasing the volumes of the engagement spaces **201** to **203** are synchronized following an increase or decrease in the overlapping margin (engagement area) of the adjacent outer rotor pieces **221** in the circumferential direction (along arrow Q) in the prescribed range. Thus, when the adjacent outer rotor pieces **221** are displaced in a direction away from each other, the "overlapping margin" is decreased, and the volume V**2** of the engagement spaces **201** to **203** is monotonically increased. When the adjacent outer rotor pieces **221** are displaced in a direction toward each other, the "overlapping margin" is increased, and the volume V**2** of the engagement spaces **201** to **203** is monotonically decreased. The operations of increasing or decreasing the volumes of the engagement spaces **201** to **203** serve a pumping function of the outer rotor **220**. The volume chamber **262** is an example of the "second volume-changing part" in the present invention.

As shown in FIG. **11**, the base **221***e* of each of the outer rotor pieces **221** is formed with an engaging part **221***h* having a prescribed inner diameter, formed by partially notching the inside in the radial direction in an arcuate shape (C shape). The engaging part **221***h* linearly extends from the end of the base **221***e* on one side to an end of the base **221***e* on another side along the axial direction and passes through the base **221***e* in the axial direction (direction X). The engaging portion **221***h* is an example of the "vane-connecting part" in the present invention.

According to the second embodiment, one volume chamber **263** having a volume V**3** is formed in a vane-housing unit **12** of the inner rotor **10** by a recess part **12***a* and a base part **31***a* of each of the vanes **30**, as shown in FIG. **14**. The volume chamber **263** is an example of the "third volume-changing part" in the present invention. Each of the vanes **30** is slid to freely appear from and disappear into the recess part **12***a*, whereby the volume V**3** of the volume chamber **263** is increased or decreased.

Thus, according to the second embodiment, one volume chamber **261** located between the adjacent vanes **30**, the volume chamber **262** formed between the outer rotor pieces **221** engaging with each other in the circumferential direction (along arrow Q) in this part, and the volume chamber **263** in the vicinity of the volume chamber **261** are configured to communicate with each other. More specifically, six volume chambers, each of which has a set of these volume chambers **261** to **263**, are formed in a state where the volume chambers are zoned around the inner rotor **10**.

According to the second embodiment, when the outer rotor **220** is rotated along arrow Q**2** with prescribed eccentricity with respect to the inner rotor **10**, as shown in FIG. **10**, the volume chambers **261**, **262**, and **263** serve the pumping function while changing their shapes (volumes) in response to this eccentricity. More specifically, the volume V**1** of the volume chamber **261**, the volume V**2** of the volume chamber **262**, and the volume V**3** of the volume chamber **263** are changed in response to the eccentricity of the outer rotor **220** with respect to the inner rotor **10** so that the volume chambers **261**, **262**, and **263** perform the pumping function.

The operation of the pumping function of the volume chamber **262** is now described. As shown in FIG. **10**, in the vicinity of a suction port **52**, a distance between the adjacent outer rotor pieces **221** in the circumferential direction is gradually increased, whereby the volume V**2** of the volume chamber **262** including the engagement spaces **201** to **203** is gradually increased. In the vicinity of a discharge port **53**, the distance between the adjacent outer rotor pieces **221** in the circumferential direction is gradually decreased, whereby the volume V**2** of the volume chamber **262** including the engagement spaces **201** to **203** is gradually decreased. In this case, the adjacent outer rotor pieces **221** engage with each other in the circumferential direction (along arrow Q) while having the engagement spaces **201** to **203** constituting the volume chamber **262**, and the total volume V**2** of the engagement spaces **201** to **203** is changed by a change in the distance between the adjacent outer rotor pieces **221** in the circumferential direction (along arrow Q). The pumping of the volume chambers **261** and **263** is similar to the pumping of the volume chambers **61** and **63** described in the aforementioned first embodiment.

Also in the oil pump **200**, one volume chamber **261** located between the adjacent vanes **30**, the volume chamber **262** formed between the outer rotor pieces **221** engaging with each other in the circumferential direction in this part, and the volume chamber **263** in the vicinity of the volume chamber **261** communicate with each other through the aforementioned notch part **221***f* (see FIG. **13**), the notch part **21***g* (see FIG. **13**), and a communication passage **13** (see FIG. **14**), and enlargement and shrinkage thereof are synchronized. Thus, when passing through the vicinity of the suction port **52**, a set of the volume chambers **261** to **263** in terms of a flow passage suctions the oil **1** while increasing their volume V**1**, volume V**2**, and volume V**3**. Then, when passing through the vicinity of the discharge port **53**, a set of the volume chambers **261** to **263** in terms of a flow passage discharges the oil **1** while decreasing their volume V**1**, volume V**2**, and volume V**3**.

Thus, in the oil pump **200**, all the deformation movement of movable parts (space parts: volume chambers **261** to **263**) existing in the housing **40**, deformed along with the rotation of a pump main body is converted to pumping. As described above, the drive force of a drive source input into the inner roto **10** is utilized for the deformation movement of the movable parts (volume chambers **261** to **263**). Therefore, also in the oil pump **200**, a mechanism in which the volume chambers **261** to **263** operate together contributes to the maximum possible conversion of the drive force of the drive source to pumping and the discharge of the oil **1**. This means that a net rate of discharge of the oil **1** per unit rotation is increased. The remaining structure of the oil pump **200** according to the second embodiment is similar to that of the oil pump **100** according to the aforementioned first embodiment.

According to the second embodiment, the following effects can be obtained.

According to the second embodiment, as hereinabove described, the oil pump **200** includes the inner rotor **10** that includes the vane-housing unit **12** (six recess parts **12***a*) housing the six vanes **30** so as to be capable of sliding in the radial direction, the outer rotor **220** that includes six bases **21***e* connecting respective tip ends **32** of the six vanes **30** on the outside in the radial direction, the volume chambers **261**, the volume V**1** of which is changed in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **220**, thereby providing the pumping function, and volume chambers **262**, which are provided in the outer rotor **220**, and the volume V**2** of which is changed by the change in the distance between the adjacent bases **221***e* in the circumferential direction in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **220**, thereby providing the pumping function. Thus, in addition to the highly-efficient pumping of the volume chambers **261** partitioned by the vanes **30**, the pumping of the volume chambers **262** newly provided in the outer rotor **220** can be effectively utilized. Therefore, the net rate of discharge of the oil **1** per unit rotation in the oil pump **200** can be sufficiently increased. Consequently, the pumping efficiency of the oil pump **200** can be improved.

According to the second embodiment, the oil pump **200** further includes volume chambers **263**, the volume V**3** of which is changed in the vane-housing unit **12** of the inner rotor **10** by the slide of the multiple vanes **30** in the radial direction in response to the eccentricity of the inner rotor **10** with respect to the outer rotor **220**, thereby providing the pumping function. Thus, the oil pump **200** can be configured to incorporate the change in the volume of the volume chambers **263** in the vane-housing unit **12** by the linear slide of the vanes **30** in the radial direction with respect to the vane-housing unit **12** into the pumping including the suction and discharge of the oil **1** without ignoring the change in the volume of the volume chambers **263** in addition to the pumping of the volume chambers **261** and the volume chambers **262**, and hence the pumping of the volume chambers **263** is effectively added so that the rate of discharge of the oil **1** per unit rotation that the oil pump **200** has can be further increased. Consequently, the oil pump **200** can be further reduced in size. Furthermore, the vanes **30** linearly sliding in the radial direction are used, and hence it is not necessary to narrow an intermediate part of each of the vanes **30** that appears from and disappears into the vane-housing unit **12** (recess part **12***a*). Therefore, no minus factor (wasted work) to newly increase the volume (newly form volume chambers) in parts on the side of the volume chambers **261** is generated in the vicinity of the volume chambers **263** during a decrease change in the volume V**3** of the volume chambers **263**, and hence the changes in the volumes of the volume chambers **261** to **263** can effectively work on the pumping of the entire oil pump **200**.

According to the second embodiment, the outer rotor **220** includes the multiple outer rotor pieces **221**, each of which is provided for each of the multiple vanes **30**, each including the base **221***e*. Furthermore, the outer rotor **220** is configured such that the multiple outer rotor pieces **221** are circumferentially arranged in a state where the adjacent outer rotor pieces **221** engage with each other so as to be capable of changing the distance therebetween in the circumferential direction (along arrow Q). Thus, properly utilizing the movement (expansion and contraction) of the adjacent outer rotor pieces **221** away from and toward each other in the circumferential direction (along arrow Q), the volume chambers **262** can perform the pumping function of repeating their enlargement and shrinkage.

According to the second embodiment, the adjacent outer rotor pieces **221** engage with each other in the circumferential direction (along arrow Q) while having the engagement spaces **201** to **203** constituting the volume chamber **262**, and the oil pump **200** is configured to change the volume V**2** of the engagement spaces **201** to **203** by the change in the distance between the adjacent outer rotor pieces **221** in the circumferential direction (along arrow Q). Thus, properly utilizing, as the volume V**2**, the engagement spaces **201** to **203** generated when the outer rotor pieces **221** engage with each other, the volume chambers **262** can perform the pumping function of repeating an increase and decrease in the volume V**2**.

According to the second embodiment, the outer rotor pieces **221** each have the first engaging piece **221***a* to the third engaging piece **221***c* engageable with each other in the circumferential direction in a state where the adjacent outer rotor pieces **221** overlap each other in the radial direction. Furthermore, the outer rotor **220** is configured to change the volume V**2** obtained by summing the engagement spaces **201** to **203** by the change in the distance between the engagement spaces **201** and **203** partially constituting the volume chamber **262** in the circumferential direction in response to the amount of overlap of the first engaging piece **221***a* to the third engaging piece **221***c*. Thus, the volume V**2** of the engagement spaces **201** to **203** can be easily increased or decreased in response to the amount of overlap of the first engaging piece **221***a* to the third engaging piece **221***c* overlapping each other, and hence the outer rotor **220** (volume chambers **262**) can easily perform the pumping function.

According to the second embodiment, each of the outer rotor pieces **221** is provided with the notch part **221***f* that allows the engagement space **203** constituting the volume chamber **262** and the volume chamber **261** to communicate with each other and the notch part **221***g* that allows the engagement spaces **201** and **202** constituting the volume chamber **262** and the volume chamber **261** to communicate with each other. Thus, the volume chamber **261** having the volume V**1** and the volume chamber **262** having the volume V**2** are allowed to communicate with each other through the notch part **221***f* and the notch part **221***g*, and hence the oil **1** can be suctioned into both the volume chamber **261** and the volume chamber **262** when the volume chambers are enlarged. When the volume chambers are shrunk, the oil **1** can be discharged from both the volume chamber **261** and the volume chamber **262**.

According to the second embodiment, the outer rotor **220** is configured such that a set of the engagement spaces **201** to **203** includes the engagement spaces **201** and **202** located on the first side (the Q**1** side in FIG. **5**) between the two adjacent vanes **30** and the engagement space **203** located on the second side (the Q**2** side in FIG. **5**) between the two adjacent vanes **30**. Thus, in the case where the generally annular outer rotor **220** is configured by sequentially connecting the adjacent outer rotor pieces **221** to each other, each of the outer rotor pieces **221** can easily engage with an outer rotor piece **221** adjacent on the first side (Q**1** side) relative to itself through the engagement spaces **201** and **202**, and each of the outer rotor pieces **221** can easily engage with an outer rotor piece **221** adjacent on the second side (Q**2** side) relative to itself through the engagement space **203**. The remaining effects of the second embodiment are similar to those of the aforementioned first embodiment.

Third Embodiment

The structure of an oil pump **300** according to a third embodiment of the present invention is now described with reference to FIGS. **1** and **15** to **23**. In the following description, the movement direction of a housing **45** housing a pump element **35** is set to a Y-axis direction, the movement direction of a spool member **360** orthogonal to this is set to a Z-axis direction, and the rotation axis direction of an inner rotor **10** is set to an X-axis direction. In the figures, the same reference numerals as those in the aforementioned first embodiment are assigned to and show structures similar to those of the first embodiment. The housing **45** is an example of the "rotor-housing unit" in the present invention, and the spool member **360** is an example of the "cam member" in the present invention.

The oil pump **300** according to the third embodiment of the present invention is mounted on a motor vehicle (not shown) including an engine **90**, as shown in FIG. **15** and has a function of pumping oil (lubricating oil) **1** in an oil pan **91** and supplying the oil **1** around pistons **92** and to a movable part (slide part) such as a crankshaft **93**.

The oil pump **300** includes the pump element **35** having a pumping function, the housing **45** housing the pump element **35** (see FIG. **1**), and a pump body **80** housing the housing **45**. The housing **45** is an example of the "rotor-housing unit" in the present invention.

The outer surface **20***a* of an annular outer rotor **20** is held to be slidable with respect to the inner peripheral surface **45***a* of the housing **45**. The pump body **80** is sealed from the front side of the plane of the figure by an unshown cover member in a state where the pump element **35** and the housing **45** are rotatably incorporated in a recessed pump-housing unit **81** of the pump body **80**, whereby six volume chambers V are formed in the pump element **35**. Each of the volume chambers V includes volume chambers **61**, **62**, and **63** (see FIG. **2**). When the inner rotor **10** is rotated along arrow Q**1** by the drive force of the crankshaft **93** in this state, the outer rotor **20** is also rotated along the same arrow Q**1** as the inner rotor **10** through six vanes **30**. The volume chambers V periodically change their shapes along with the rotation of the pump element **35** along arrow Q**1**, thereby providing the pumping function.

The pump-housing unit **81** is formed with a suction port **52** that suctions the oil **1** and a discharge port **53** that discharges the oil **1**. The suction port **52** is connected to an intake oil passage **95** extending from the oil pan **91**. The pump body **80** includes a discharge oil passage **54** connected to the discharge port **53** of the pump-housing unit **81**, and the discharge oil passage **54** is connected to an external supply oil passage **96** supplying the oil **1** to each part of the engine **90**.

The pump-housing unit **81** has such a shape that the housing **45** is housed so as to be movable back and forth along the Y-axis direction. Specifically, the pump-housing unit **81** has an inner surface **81***a* extending in the Y-axis direction on each of a Z**1** side and a Z**2** side, and the housing **45** has an outer surface **45***b* extending in the Y-axis direction on each of the Z**1** side and the Z**2** side. The housing **45** has such an outer shape that the housing **45** is fitted into the pump-housing unit **81** while the outer surface **45***b* faces the inner surface **81***a* of the pump-housing unit **81**. The outer surface **45***b* of the housing **45** is slid with respect to the inner surface **81***a* of the pump-housing unit **81** so that the housing **45** is linearly moved along arrow Y**1** or arrow Y**2** with respect to the pump-housing unit **81**. The Y-axis direction is an example of the "first direction" in the present invention.

Sealing members **47** are fitted into the outer surface **45***b* of the housing **45** on the Z**2** side. The respective sealing members **47** made of a rubber (resin) material are provided in the outer surface **45***b* on a Y**1** side and the outer surface **45***b* on a Y**2** side. These sealing members **47** prevent the oil **1** having a relatively high pressure on the side of the discharge port **53** in the pump-housing unit **81** from being leaked to the suction port **52** (intake oil passage **95**), which is a region having a relatively low pressure.

The pump-housing unit **81** further has an inner surface **81***b* extending in an arcuate shape on each of the Y**1** side and the Y**2** side, as shown in FIGS. **15** and **16**. The inner surface **81***b* on the Y**1** side is provided with a spring-storing unit **85** (see FIG. **15**), and the inner surface **81***b* on the Y**2** side is provided with an opening **86**. As shown in FIG. **16**, a through-hole **87** passing through the pump body **80** in the X-axis direction is formed in a central part held between the suction port **52** and the discharge port **53** of the pump-housing unit **81**. A drive shaft (not shown) for rotating the inner rotor **10** (see FIG. **15**) is configured to be inserted into the through-hole **87**. This drive shaft is fixed to a shaft hole **11** of the inner rotor **10** in a state where the inner rotor **10** is arranged in the pump-housing unit **81**. The housing **45** further has an outer surface **45***c* extending in an arcuate shape on each of the Y**1** side and the Y**2** side, as shown in FIG. **15**. The outer surface **45***c* on the Y**1** side is provided with a seat part **46** having a flat surface, and the outer surface **45***c* on the Y**2** side is provided with a convex part **48**. The convex part **48** is an example of the "cam engaging part" in the present invention.

The housing **45** is arranged in the pump-housing unit **81** such that the convex part **48** is directed to a side (Y**2** side) on which the opening **86** of the pump-housing unit **81** is provided. The side (Y**1** side) of the spring-storing unit **85** opposite to the housing **45** is sealed by a plug screw **307** in a state where a coiled spring **305** is fitted into the spring-storing unit **85** and the seat part **46** is pressed along arrow Y**2**. Thus, the housing **45** is constantly urged to the Y**2** side on which the opening **86** is provided by the urging force of the spring **305**. When the housing **45** is located farthest on Y**2** side, a tip end of the convex part **48** protrudes into an oil passage part **57** described later through the opening **86**. The spring **305** is an example of the "first urging member" in the present invention.

The inner rotor **10** has a rotation center R fixedly arranged. The housing **45** holding the outer rotor **20** is moved by a prescribed amount in the Y-axis direction (along arrow Y**1** or arrow Y**2**), whereby the rotation center U of the outer rotor **20** is eccentric in a transverse direction (along arrow Y**1** or arrow Y**2**) relative to the rotation center R of the inner rotor **10**. In this case, a tip end **32** of each of the vanes **30** protrudes from a recess part **12***a* of a vane-housing unit **12** toward an outer rotor piece **21** by an amount in response to eccentricity in each rotational position (rotational angle) along arrow Q**1**. Therefore, each of the vanes **30** is rotationally moved along arrow Q**1** while appearing from and disappearing into the recess part **12***a* along with the rotation of the inner rotor **10** and allows the outer rotor **20** to be rotated along arrow Q**1** in an accompanying manner.

At this time, in each of the volume chambers V, its volume is periodically changed between a minimum value and a maximum value, following the shape deformation of the volume chambers V. The oil **1** is suctioned according to a decrease in the pressure of the volume chambers V following the change of the volume of each of the volume chambers V from the minimum value to the maximum value, and the suctioned oil **1** is discharged according to an increase in the pressure of the volume chambers V following the change of the volume of each of the volume chambers V from the maximum value to the minimum value. Thus, the oil pump **300** is configured to operate with the pumping function.

According to the third embodiment, the oil pump **300** includes the spool member **360**, as shown in FIG. **15**. The spool member **360** is incorporated in the pump body **80** and is linearly moved in the Z-axis direction orthogonal to the

Y-axis direction in response to the discharge pressure P (the oil **1** on a discharge side is dotted in FIG. **15**) of the oil **1** from the discharge port **53**. The housing **45** is moved in the Y-axis direction following the linear movement of the spool member **360** in the Z-axis direction. The spool member **360** has a function of increasing and decreasing the amount of movement of the housing **45** in the Y-axis direction (=the eccentricity of the rotation center U of the outer rotor **20** with respect to the rotation center R of the inner rotor **10**). The Z-axis direction is an example of the "second direction" in the present invention. This point is now described in detail.

As shown in FIG. **15**, the pump body **80** is formed with the oil passage part **57** for drawing the oil **1** is formed in the middle of the discharge oil passage **54**. The oil passage part **57** has a circular cross-section except for a part corresponding to the opening **86**, and the spool member **360** extending in the Z-axis direction is inserted into the oil passage part **57**. The oil passage part **57** has such a shape that the spool member **360** is housed so as to be movable back and forth along arrow **Z1** or arrow **Z2** in the Z-axis direction. Arrow **Z1** is an example of the "one direction of the second direction" in the present invention. Arrow **Z2** is an example of the "another direction of the second direction" in the present invention.

The spool member **360** includes a main body part **361** extending in the form of a bar in the Z-axis direction, a cam-shaped part **362** formed in a region of the main body part **361** closer to a central part along the Z-axis direction, a recessed seat part **363** formed in a first end (Z1 side), and a pressure-receiving surface **364** formed in a second end (Z2 side), as shown in FIG. **17**. The spool member **360** is inserted into the oil passage part **57** such that the pressure-receiving surface **364** is directed to the discharge oil passage **54**, and the side (Z1 side) of the spool member **360** opposite to the oil passage part **57** is sealed by a plug spring **308** in a state where a coiled spring **306** is fitted into the seat part **363**. The cam-shaped part **362** is an example of the "cam region" in the present invention. The spring **306** is an example of the "second urging member" in the present invention.

The cam-shaped part **362** is formed to have a prescribed concave-convex shape by cutting one side surface of the main body part **361**, and in a part other than the cam-shaped part **362**, a cylindrical outer surface **361***a* remains. The outer surface **361***a* of the spool member **360** is slid with respect to the inner surface **57***a* (see FIG. **15**) of the oil passage part **57** in a state where the main body part **361** is slidingly inserted into the oil passage part **57** such that the outer surface **361***a* faces the inner surface **57***a*, whereby the spool member **360** is linearly moved along arrow **Z1** or arrow **Z2** with respect to the oil passage part **57**. The inner diameter of the oil passage part **57** is slightly larger than the outer diameter of the spool member **360**, and the cylindrical outer surface **361***a* of the spool member **360** is smoothly slid with respect to the inner surface **57***a* of the oil passage part **57**.

As shown in FIG. **15**, the spool member **360** is arranged in the oil passage part **57**, whereby the oil passage part **57** is divided into a pressure-receiving region **58***a* where the pressure of the oil **1** discharged from the discharge port **53** directly acts along arrow **Z1** and an adjustment region **58***b* including a region provided with the cam-shaped part **362** and the seat part **363**, where the spool member **360** is allowed to be moved without directly receiving the discharge pressure of the oil **1**. In a state where the spool member **360** is arranged in the oil passage part **57**, the cam-shaped part **362** is arranged to face the convex part **48** of the housing **45** protruding into the adjustment region **58***b* of the oil passage part **57** through the opening **86**. In this case, the tip end of the convex part **48** of the housing **45** comes into contact with a prescribed part of the cam-shaped part **362** from the **Y1** side by the urging force of the spring **305**.

Thus, according to the third embodiment, when the oil **1** discharged from the discharge port **53** is drawn into the pressure-receiving region **58***a* of the oil passage part **57** through the discharge oil passage **54** with the discharge pressure P during operation of the pump element **35**, the oil **1** acts on the pressure-receiving surface **364** of the spool member **360** so that the spool member **360** is linearly moved along arrow **Z1**. Along with the linear movement of the cam-shaped part **362** along arrow **Z1** in response to the discharge pressure P, the housing **45** is moved along arrow **Y1** or arrow **Y2** with respect to the pump body **80** through the convex part **48** coming into contact with the cam-shaped part **362**. Consequently, in the pump element **35**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased or decreased along with an increase or decrease in the amount of movement of the housing **45** in the Y-axis direction.

When the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is relatively small (a state in FIG. **21**, for example), the pumping amount resulting from the enlargement and shrinkage of the six volume chambers V volumetrically integrated is relatively small, and the rate of discharge of the oil **1** at the same rotational speed is relatively small. In this case, an increase (the inclination of a straight line (discharge pressure characteristics) shown in FIG. **22**) in the discharge pressure P following an increase in the rotational speed is modest. When the eccentricity is relatively large (a state in FIG. **15**, for example), the pumping amount resulting from the enlargement and shrinkage of the six volume chambers V volumetrically integrated is relatively large, and the rate of discharge of the oil **1** at the same rotational speed is relatively large. In this case, an increase in the discharge pressure P following an increase in the rotational speed is large (the inclination of the straight line shown in FIG. **22** is increased).

According to the third embodiment, the cam-shaped part **362** of the spool member **360** has such a surface shape (concave-convex shape) that the amount D of protrusion of the cam-shaped part **362** in the Y-axis direction with respect to the convex part **48** of the housing **48** is changed (increased or decreased) along the Z-axis direction. Thus, the housing **45** is moved along arrow **Y1** or arrow **Y2** in response to the change (the undulating state of the cam-shaped part **362**) in the amount D of protrusion of the cam-shaped part **362** following the movement of the spool member **360** along arrow **Z1**, so that the eccentricity of the rotation center U of the outer rotor **20** with respect to the rotation center R of the inner rotor **10** is increased or decreased.

More detailedly, the cam-shaped part **362** is formed by connecting a cam region **71**, a cam region **72**, a cam region **73**, a cam region **74**, and a cam region **75** in this order along the Z-axis direction from the first end (Z1 side) toward the second end (Z2 side). The cam regions **71**, **72**, and **73** are examples of the "first cam region", the "second cam region", and the "third cam region" in the present invention, respectively.

Based on the height (the amount D of protrusion along arrow **Y1**) of the cam region **71**, the cam region **71** is flattened along the Z-axis direction and has a constant height along the Z-axis direction. The cam region **72** is continuously connected to the cam region **71**, and the height (the amount D of protrusion along arrow **Y1**) of the cam region **72** is gradually increased from the cam region **71** toward a **Y2** direction. The cam region **73** is connected to an end point part of the cam region **72** on the **Z2** side so as to be bent along arrow **Y2**, and the height (the amount D of protrusion along arrow **Y1**) of the cam region **73** is gradually decreased from the cam region **72** toward the **Y2** direction. The cam region **74** is flattened along the Z-axis direction while maintaining the height (the amount D of protrusion along arrow **Y1**) of an end point part of the cam region **73** on the **Z2** side, and the height of the cam region **74** in that position is maintained constant. The height of the cam region **74** is larger than the height of the cam region **71**. The cam region **75** is continuously connected to an end point part of the cam region **74** on the **Z2** side, and the height (the amount D of protrusion along arrow **Y1**) of the cam region **75** is gradually increased from the cam region **74** toward the **Y2** direction.

According to the third embodiment, when the discharge pressure P of the oil **1** from the discharge port **53** is within a pressure range **P1** (see FIG. **15**), the cam region **71** is a region arranged to face the convex part **48** of the housing **45**. When the discharge pressure P of the oil **1** from the discharge port **53** is within a pressure range **P2** (see FIG. **18**) larger than the pressure range **P1**, the cam region **72** is a region engaging with the convex part **48** of the housing **45**. When the discharge pressure P of the oil **1** from the discharge port **53** is within a pressure range **P3** (see FIG. **19**) larger than the pressure range **P2**, the cam region **73** is a region engaging with the convex part **48** of the housing **45**. The pressure range **P1**, the pressure range **P2**, and the pressure range **P3** are examples of the "first pressure range", the "second pressure range", and the "third pressure range" in the present invention, respectively.

In addition to the above, when the discharge pressure P of the oil **1** from the discharge port **53** is within a pressure range **P4** (see FIG. **20**) larger than the pressure range **P3**, the cam region **74** is a region engaging with the convex part **48** of the housing **45**. When the discharge pressure P of the oil **1** from the discharge port **53** is within a pressure range **P5** (see FIG. **21**) larger than the pressure range **P4**, the cam region **75** is a region engaging with the convex part **48** of the housing **45**. There is a relationship of the pressure range **P1**<the pressure range **P2**<the pressure range **P3**<the pressure range **P4**<the pressure range **P5**.

When the convex part **48** of the housing **45** is arranged to face the cam region **71** (see FIG. **15**), the eccentricity of the rotation center U of the outer rotor **20** with respect to the rotation center R of the inner rotor **10** is eccentricity **A1**, which is a maximum value. When the convex part **48** of the housing **45** is arranged to face the cam region **75** (see FIG. **21**), the eccentricity of the rotation center U of the outer rotor **20** with respect to the rotation center R of the inner rotor **10** is eccentricity **A5**, which is a minimum value.

In the oil pump **300**, when the spool member **360** is moved along arrow **Z1** so as to sequentially switch the cam-shaped part **362** of the spool member **360** to the cam region **71**, the cam region **72**, the cam region **73**, the cam region **74**, and the cam region **75** in response to an increase in the discharge pressure P of the oil **1** from the discharge port **53**, the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** (the eccentricity of the outer rotor **20** with respect to the inner rotor **10**) is maintained (unchanged) in the case of the cam region **71** (see FIG. **15**) whereas the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** (the eccentricity of the outer rotor **20** with respect to the inner rotor **10**) is decreased in the case of the cam region **72** (see FIG. **18**).

The oil pump **300** is configured such that in the case of the cam region **73** (see FIG. **19**), the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** (the eccentricity of the outer rotor **20** with respect to the inner rotor **10**) is increased (the eccentricity is reversed in an increasing direction) from the state where the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** is decreased in the case of the cam region **72**. Furthermore, the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** (the eccentricity of the outer rotor **20** with respect to the inner rotor **10**) is maintained (the increased state in the case of the cam region **73** is unchanged) in the case of the cam region **74** (see FIG. **20**) whereas the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** (the eccentricity of the outer rotor **20** with respect to the inner rotor **10**) is decreased again in the case of the cam region **75** (see FIG. **21**) (the housing **45** is moved such that the eccentricity is decreased).

More specifically, the cam region **71** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is maintained at (fixed to) the eccentricity **A1**. The cam region **72** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is (decreased to) eccentricity **A2** smaller than the eccentricity **A1**. The cam region **73** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is increased to eccentricity **A3** larger than the minimum value of the eccentricity **A2**. The maximum value of the eccentricity **A3** is smaller than the maximum value (=eccentricity **A1**) of the eccentricity **A2**. The eccentricity **A1**, the eccentricity **A2**, and the eccentricity **A3** are examples of the "first eccentricity", the "second eccentricity", and the "third eccentricity" in the present invention, respectively.

In addition to the above, the cam region **74** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is maintained at eccentricity **A4**, which is the maximum value of the eccentricity **A3** (but a value smaller than the maximum value of the eccentricity **A2**), and the cam region **75** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is decreased to the eccentricity **A5** smaller than the eccentricity **A4**.

Therefore, the cam region **72** is provided such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is decreased from the eccentricity **A1** (=the maximum value of the eccentricity **A2**) to the eccentricity **A2** (=the minimum value of the eccentricity **A2**) toward the cam region **73**. The cam region **73** is provided such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased from the eccentricity **A2** (=the minimum value of the eccentricity **A2**) to the eccentricity **A3** (restricted to the maximum value of the eccentricity **A2**) toward the cam region **74**. The cam region **75** is provided such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased from the eccentricity **A4**

(=the maximum value of the eccentricity A3) to the eccentricity A5 (=the minimum value of the eccentricity A5) toward a side opposite to the cam region **74**.

The cam region **71**, the cam region **72**, the cam region **73**, the cam region **74**, and the cam region **75** are continuously provided, and the convex part **48** of the housing **45** is moved in the Y-axis direction (along arrow Y**1** or arrow Y**2**) by sequentially sliding along the cam region **71**, the cam region **72**, the cam region **73**, the cam region **74**, and the cam region **75** following the movement of the spool member **360** along arrow Z**1**.

As discussed in relation to the discharge pressure P, according to the third embodiment, when the discharge pressure P of the oil **1** is within the pressure range P**1** (see FIG. **15**), the cam region **71** of the spool member **360** is linearly moved to a position corresponding to the convex part **48** of the housing **45** so that the housing **45** is linearly moved to a first eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is maintained at the eccentricity A**1**, which is the maximum eccentricity. In the pressure range P**2** (see FIG. **18**), the cam region **72** of the spool member **360** is linearly moved to a position engaging with the convex part **48** of the housing **45** so that the housing **45** is linearly moved to a second eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**2** smaller than the eccentricity A**1**. In the pressure range P**3** (see FIG. **19**), the cam region **73** of the spool member **360** is linearly moved to a position engaging with the convex part **48** of the housing **45** so that the housing **45** is linearly moved to a third eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**3** larger than the minimum value of the eccentricity A**2**.

In the pressure range P**4** (see FIG. **20**), the cam region **74** of the spool member **360** is linearly moved to a position engaging with the convex part **48** of the housing **45** so that the housing **45** is linearly moved to a fourth eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is maintained at the eccentricity A**4**, which is the maximum of the eccentricity A**3**. In the pressure range P**5** (see FIG. **21**), the cam region **75** of the spool member **360** is linearly moved to a position engaging with the convex part **48** of the housing **45** so that the housing **45** is linearly moved to a fifth eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**5** smaller than the eccentricity A**4**.

According to the third embodiment, the suction port **52** (intake oil passage **95**) in the pump-housing unit **81** communicates with the adjustment region **58***b* provided with the cam-shaped part **362** of the spool member **360** through the opening **86** in a region on the Y**2** side, as shown in FIG. **15**. Therefore, during operation of the pump element **35**, at least part of the oil **1** suctioned into the suction port **52** through the opening **86** is drawn into the cam-shaped part **362** (cam regions **71** to **75**) of the spool member **360**. Thus, when the housing **45** is moved in the Y-axis direction through the cam-shaped part **362** provided in the spool member **360**, the oil **1**, the pressure of which is lower than the discharge pressure P, is easily drawn into the vicinity of the cam-shaped part **362** (adjustment region **58***b*), and the cam regions **71** to **75** are lubricated. The spool member **360** is formed with a through-hole **365** passing through the seat part **363** (bottom part) in the Z-axis direction such that a side on which the spring **306** is provided and the cam region **71** (cam-shaped part **362**) communicate with each other. Therefore, at least part of the oil **1** suctioned into the suction port **52** is drawn into not only the cam-shaped part **362** but also a space part between the plug spring **308** and the seat part **363**. Thus, even when the volume of the space part (adjustment region **58***b*) between the plug spring **308** and the seat part **363** is increased or decreased following the forward or reverse movement of the spool member **360** in the Z-axis direction, the oil **1** in a low pressure (intake pressure) state simply reversibly flows and does not interrupt the movement of the spool member **360** in the Z-axis direction.

When the rotation center R of the inner rotor **10** and the rotation center U of the outer rotor **20** completely coincide with each other, the tip end **32** of each of the vanes **30** protrudes from the recess part **12***a* (vane-housing unit **12**) toward the outer rotor piece **21** by the same amount. Therefore, even when the inner rotor **10** is rotated, each of the vanes **30** is rotationally moved without changing the amount of protrusion and only allows the outer rotor **20** to be rotated in an accompanying manner, and hence the oil pump **300** does not perform the pumping function.

Due to the aforementioned structure, the oil pump **300** has the following characteristics (the discharge pressure characteristics of the oil **1** with respect to the rotational speed of the inner rotor **10**). FIG. **22** shows the characteristics of the discharge pressure (vertical axis) of the oil **1** discharged from the pump body **80** (discharge oil passage **54**) with respect to the rotational speed (horizontal axis) of the engine **90** (crankshaft **93**) as the operating characteristics of the oil pump **300**. FIG. **22** shows not only the operating characteristics of the oil pump **300** but also the characteristics (discharge pressure characteristics) of a conventional oil pump as a comparative example. In the oil pump as the comparative example (conventional example), when the housing (rotor-housing unit) is moved in one direction along with an increase in the discharge pressure of the oil, the eccentricity of the housing with respect to the inner rotor (rotor) is monotonically decreased, and the pump capacity is decreased. The following description is with reference to FIGS. **15** and **18** to **21** according to the movement position of the spool member **360**. FIGS. **18** to **20** illustrate the schematic structure of the pump element **35**, and the outer shape of the annular outer rotor **20** (outer rotor piece **21**) is shown by broken lines.

In a section in which the rotational speed of the engine **90** (see FIG. **15**) is up to about 1100 rotations per minute in FIG. **22**, the cam region **71** of the spool member **360** is arranged to face the convex part **48** of the housing **45**, as shown in FIG. **15**. In this case, the cam region **71** flattened along the Z-axis direction is only moved along arrow Z**1** even when the rotational speed of the engine **90** (crankshaft **93**) is increased so that the spool member **360** is moved along arrow Z**1** along with an increase in the discharge pressure P of the oil **1** from the discharge port **53**. Thus, the amount of movement of the convex part **48** in the Y-axis direction is unchanged. In this case, the eccentricity of the rotation center U of the outer rotor **20** with respect to the rotation center R of the inner rotor **10** is maintained at the eccentricity A**1**, which is a maximum value. Therefore, the discharge pressure characteristics are shaped like a characteristic G**1** in FIG. **22** when the housing **45** is maintained at the eccentricity A**1**. A straight line (a broken line on which the characteristic G**1** extends) having the inclination of the characteristic G**1** corresponds to a maximum eccentricity line in the oil pump **300**. A range of the characteristic G**1** corresponds to the pressure range P**1** of the discharge pressure P.

Then, when the rotational speed of the engine **90** exceeds about 1100 rotations per minute and the discharge pressure P exceeds the maximum value of the pressure range P**1**, a position of the spool member **360** moved along arrow Z**1**, engaging with the convex part **48** is switched from the cam region **71** to the cam region **72**. Thus, the oil pump **300** shifts from the state in FIG. **15** to a state in FIG. **18**. When the spool member **360** is moved along arrow Z**1** along with an increase in the discharge pressure P of the oil **1** from the discharge port **53**, as shown in FIG. **18**, the convex part **48** is gradually moved along arrow Y**1** to follow the shape (inclined shape) of the cam region **72**. In other words, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is decreased along with an increase in the amount D of protrusion along arrow Y**1** when the convex part **48** engages with the cam region **72**. Therefore, the housing **45** is changed (decreased) from the eccentricity A**1** (constant value) to the eccentricity A**2**. In this case, the discharge pressure characteristics are shaped like a characteristic G**2** in FIG. **22**. A range of the characteristic G**2** corresponds to the pressure range P**2** of the discharge pressure P.

Then, when the rotational speed of the engine **90** exceeds about 3600 rotations per minute and the discharge pressure P exceeds the maximum value of the pressure range P**2**, a position of the spool member **360** moved along arrow Z**1**, engaging with the convex part **48** is switched from the cam region **72** to the cam region **73**. Thus, the oil pump **300** shifts from the state in FIG. **18** to a state in FIG. **19**. When the spool member **360** is moved along arrow Z**1** along with an increase in the discharge pressure P of the oil **1** from the discharge port **53**, as shown in FIG. **19**, the convex part **48** is gradually moved along arrow Y**2** to follow the shape (inclined shape) of the cam region **73**. In other words, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased along with a decrease in the amount D of protrusion along arrow Y**1** when the convex part **48** engages with the cam region **73**. Therefore, the housing **45** is changed (increased) to the eccentricity A**3** larger than the maximum value of the eccentricity A**2** after the maximum value of the eccentricity A**2**. In this case, the discharge pressure characteristics are shaped like a characteristic G**3** in FIG. **22**. A range of the characteristic G**3** corresponds to the pressure range P**3** of the discharge pressure P.

Then, when the rotational speed of the engine **90** exceeds about 3900 rotations per minute and the discharge pressure P exceeds the maximum value of the pressure range P**3**, a position of the spool member **360** moved along arrow Z**1**, engaging with the convex part **48** is switched from the cam region **73** to the cam region **74**. Thus, the oil pump **300** shifts from the state in FIG. **19** to a state in FIG. **20**. When the spool member **360** is moved along arrow Z**1** along with an increase in the discharge pressure P of the oil **1** from the discharge port **53**, as shown in FIG. **20**, the convex part **48** is not moved in the Y-axis direction to follow the shape (flat shape) of the cam region **74**. In other words, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is maintained at that position (the maximum value of the eccentricity A**3**=the eccentricity A**4** (constant value)) when the convex part **48** engages with the cam region **74**. In this case, the discharge pressure characteristics are shaped like a characteristic G**4** in FIG. **22**. A range of the characteristic G**4** corresponds to the pressure range P**4** of the discharge pressure P. The inclination of the characteristic G**4** is smaller than the inclination of the characteristic G**1**. In other words, the eccentricity of the housing **45** is decreased from the eccentricity A**1** to the eccentricity A**4**, and the pump capacity (a net rate of discharge per rotation) is decreased. In other words, a straight line (a broken line on which the characteristic G**4** extends) having the inclination of the characteristic G**4** corresponds to an eccentricity line between the maximum and the minimum in the oil pump **300**.

Then, when the rotational speed of the engine **90** exceeds about 5300 rotations per minute corresponding to the pressure P**4** and the discharge pressure P reaches the pressure P**4**, a position of the spool member **360** moved along arrow Z**1**, engaging with the convex part **48** is switched from the cam region **74** to the cam region **75**. Thus, the oil pump **300** shifts from the state in FIG. **20** to the state in FIG. **21**. When the spool member **360** is moved along arrow Z**1** along with an increase in the discharge pressure P of the oil **1** from the discharge port **53**, as shown in FIG. **21**, the convex part **48** is gradually moved along arrow Y**1** to follow the shape (inclined shape) of the cam region **75**. In other words, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is decreased again along with an increase in the amount D of protrusion along arrow Y**1** when the convex part **48** engages with the cam region **75**. Therefore, the housing **45** is changed (decreased) from the eccentricity A**4** (constant value) to the eccentricity A**5**. In this case, the discharge pressure characteristics are shaped like a characteristic G**5** in FIG. **22**. A straight line (a broken line on which the characteristic G**5** extends) having the inclination of the characteristic G**5** corresponds to a minimum eccentricity line in the oil pump **300**. A range of the characteristic G**5** corresponds to the pressure range P**5** of the discharge pressure P. Thus, the oil pump **300** has the discharge pressure characteristics obtained by connecting the characteristics G**1** to G**5**, as shown by a bold solid line.

In the oil pump according to the comparative example, on the other hand, in a section in which the rotational speed of the engine **90** is up to about 2900 rotations per minute, the discharge pressure P of the oil **1** is increased following an increase in the rotational speed of the engine **90** (crankshaft **93**), but the eccentricity (in this case, the eccentricity A**1**) of the housing (rotor-housing unit) is unchanged. Therefore, as shown in FIG. **22**, the discharge pressure characteristics are shaped like a characteristic H**1** obtained by extending a graph to a position in which the rotational speed of the engine **90** reaches about 2900 rotations per minute while maintaining an inclination equal to that of the characteristic G**1** in the oil pump **300** (see FIG. **15**). Then, when the rotational speed of the engine **90** exceeds about 2900 rotations per minute, the housing (rotor-housing unit) is moved in one direction on the basis of the discharge pressure P. Thus, the eccentricity (rotor-housing unit) of the housing is promptly decreased from the eccentricity A**1**, which is the maximum value, to the eccentricity A**5** (A**1**>A**5**), which is a minimum value range. Therefore, at about 2900 rotations per minute, the discharge pressure characteristics follow a characteristic H**2** having an inclination smaller than that of the characteristic H**1**. The characteristic H**2** extends to a position where the rotational speed of the engine **90** is about 2900 rotations per minute with the same inclination as that of the characteristic G**5** in the oil pump **300** (see FIG. **15**). Thus, the oil pump according to the comparative example has the discharge pressure characteristics obtained by connecting the characteristic H**1** (maximum eccentricity line) and the characteristic H**2** (minimum eccentricity line) shown by bold broken lines.

As shown in FIG. **22**, in the motor vehicle mounted with the oil pump **300**, operation points S**1** to S**4** for supplying the oil **1** by prescribed oil pressures are set according to the rotational speed of the engine **90**. In the oil pump **300** according to the third embodiment, the discharge pressure characteristics (characteristics G**1** to G**5**) satisfying the supply pressure of the oil **1** required at the operation points S**1** to S**4** are achieved. Also in the oil pump according to the comparative example, the discharge pressure characteristics (characteristics H**1** and H**2**) satisfy this point. However, the required discharge pressure characteristics are only required to pass through the upper vicinity of the operation points S**1** to S**4**, and at least the discharge pressure P required in the characteristic G**4** in the oil pump **300** is satisfied when attention is particularly paid to the operation point S**3** (about 4000 rotations per minute), which is a medium-speed rotation region of the engine **90**.

On the other hand, the oil pump according to the comparative example has only the two inclinations of the characteristics H**1** and H**2**, and hence the pressure required at the operation point S**3** (about 4000 rotations per minute) is satisfied, but the oil **1** is supplied at the discharge pressure P (characteristic H**2**) far exceeding this pressure. The oil pump **300** has the characteristics G**2** to H**4**, and hence unlike the oil pump according to the comparative example, no excessive discharge pressure P is generated in the oil pump **300** while the pressure of the oil **1** required at the operation point S**3** is satisfied. When the spool member **360** (see FIG. **15**) is linearly moved along arrow Z**1**, which is one direction, the housing **45** is reversibly moved in two directions along arrow Y**1** and arrow Y**2** with respect to the pump body **80** while following the concave-convex shape of the cam-shaped part **362** (see FIG. **15**), whereby change from the characteristic G2 to the characteristic H**4** is achieved. That the oil pump **300** according to the third embodiment has sections of the characteristics G2 to G4 having peaks and valleys to be bent between the characteristic G1 and the characteristic G**5**, unlike change from the characteristic H**1** (a characteristic obtained by extending the characteristic G**1** to the medium-speed rotation region) to the characteristic H**2** (a characteristic obtained by extending the characteristic G**5** to the medium-speed rotation region) in the oil pump according to the comparative example means that the pump element **35** (see FIG. **15**) generates no wasted (excessive) oil even at the same rotational speed. The oil **1** having a wasted oil pressure (oil amount) pushes up a relief valve (not shown) etc. and is returned to the oil pan **91** through a relief path. In the oil pump **300**, no wasted (excessive) oil pressure (oil amount) is generated, and hence power for driving the pump element **35** is reduced. A reduction in pump power also contributes to a reduction in the load (loss) of the engine **90** and leads to an improved fuel consumption rate.

When the rotational speed of the engine **90** (see FIG. **15**) is changed from a high state to a low state, the discharge pressure characteristics are changed in a direction opposite to the above. In other words, the discharge pressure P is changed in the order of the characteristics G**5**, G**4**, G3, G2, and G1.

According to the third embodiment, between the characteristics of the eccentricity of the outer rotor **20** with respect to the inner rotor **10** resulting from the movement of the housing **45** in the Y-axis direction (along arrow Y1 or arrow Y2) in response to the change in the amount D of protrusion of the cam-shaped part **362** generated when the spool member **360** is linearly moved along arrow Z1 and the characteristics of the eccentricity of the outer rotor **20** with respect to the inner rotor **10** resulting from the movement of the housing **45** in a direction X (along arrow Y1 or arrow Y2) in response to the change in the amount D of protrusion of the cam-shaped part **362** generated when the spool member **360** is linearly moved along arrow Z2, there is a hysteresis error.

Specifically, when the rotational speed of the engine **90** (see FIG. **15**) is increased, as shown in FIGS. **18** to **20**, the spool member **360** is linearly moved along arrow Z1 in response to the discharge pressure P of the oil **1**, and the tip end of the convex part **48** of the housing **45** is slid with respect to the cam regions **72**, **73**, and **74** in this order. Thus, the discharge pressure characteristics follow a path of the characteristic G**2**, the characteristic G**3**, and the characteristic G**4**, extending from the left side of the plane of the figure to the right side thereof, as shown in FIG. **23**. When the rotational speed of the engine **90** is decreased, on the other hand, the spool member **360** is linearly moved along arrow Z2 by the urging force of the spring **306**, and the tip end of the convex part **48** of the housing **45** is slid with respect to the cam regions **74**, **73**, and **72** in this order. Thus, the discharge pressure characteristics follow a path of a characteristic G**41**, a characteristic G**31**, a characteristic G**21**, extending from the right side of the plane of the figure to the left side thereof, as shown in FIG. **23**.

Between a range of the rotational speed of the engine corresponding to each of the characteristic G**2**, the characteristic G**3**, and the characteristic G**4** during an increase in the rotational speed of the engine and a range of the rotational speed of the engine corresponding to each of the characteristic G**21**, the characteristic G**31**, and the characteristic G**41** during a decrease in the rotational speed of the engine, there is a prescribed hysteresis error. In this case, during an increase in the rotational speed of the engine, the discharge pressure characteristics do not switch from the characteristic G**2** to the characteristic G**3** and from the characteristic G**3** to the characteristic G**4** unless the rotational speed of the engine reaches a relatively high rotational speed. On the other hand, during a decrease in the rotational speed of the engine, the discharge pressure characteristics do not switch from the characteristic G**41** to the characteristic G**31** and from the characteristic G**31** to the characteristic G**21** unless the rotational speed of the engine reaches a rotational speed lower than that during an increase in the rotational speed of the engine. Therefore, in the oil pump **300**, it is necessary to generate a prescribed rotational speed R**1** during an increase in the rotational speed of the engine **90** when a prescribed discharge pressure P (vertical axis) is applied to the discharged oil **1**. On the other hand, the oil pump **300** is configured to maintain the discharge pressure P to a rotational speed R**2** lower than the rotational speed R**2** (R**2**<R**1**) at which the discharge pressure P is obtained during an increase and decrease the discharge pressure P after the rotational speed of the engine reaches a rotational speed lower than the rotational speed R**2**, during a decrease in the rotational speed of the engine **90**.

The reason for this is as follows. Taking the cam region **72** of the spool member **360** as an example, when the spool member **360** is linearly moved along arrow Z**1** and the tip end of the convex part **48** is slid along the inclined surface shape of the cam region **72** from the Z**1** side (a side on which the amount D of protrusion is smaller) to the Z**2** side (a side on which the amount D of protrusion is larger) under a condition where the convex part **48** of the housing **45** is brought into contact with (engages with) the cam region **72** having a prescribed inclination angle in a direction from the Z1 side to the Z2 side, in which the amount D of protrusion is increased, along arrow Y**2** by the urging force of the spring **305**, as shown in FIG. **15**, a total load F**1**+F**2** (acting along arrow Z**2**) of the pushing force F**1** of the spring **306** acting along arrow Z**2** and a spring load (pushing force) F**2** split along arrow Z**2** on the basis of the inclination angle of the cam region **72** when the inclined surface of the cam region **72** is pushed along arrow Y**2** through the tip end of the convex part **48** by the urging force of the spring **305** is applied to the spool member **360**. Therefore, the oil pump **300** requires a pushing force larger than the total load F**1**+F**2** acting along arrow Z**2** to act on the pressure-receiving surface **364** along arrow Z**1** in order to linearly move the spool member **360** along arrow Z**1**.

When the spool member **360** is linearly moved along arrow Z**2** and the tip end of the convex part **48** is slid along the inclined surface shape of the cam region **72** from the Z**2** side (the side on which the amount D of protrusion is larger) to the Z**1** side (the side on which the amount D of protrusion is smaller), on the other hand, a load F**1**-F**2** (acting along arrow Z**2**) obtained by subtracting a spring load (pushing force) F**2** split along arrow Z**1** on the basis of the inclination angle of the cam region **72** when the inclined surface of the cam region **72** is pushed along arrow Y**2** through the tip end of the convex part **48** by the urging force of the spring **305** from the pushing force F**1** of the spring **306** acting along arrow Z**2** is applied to the spool member **360**. Therefore, the oil pump **300** requires a pushing force smaller than the load F**1**-F**2** acting along arrow Z**2** to act on the pressure-receiving surface **364** along arrow Z**1** in order to linearly move the spool member **360** along arrow Z**2**. Thus, there is a difference in a pushing force (the discharge pressure P of the oil **1**) to be applied to the pressure-receiving surface **364** of the spool member **360** along arrow Z**1** between when the tip end of the convex part **48** ascends the inclined surface of the cam region **72** (the spool member **360** is moved along arrow Z**1**) and when the tip end of the convex part **48** descends the inclined surface of the cam region **72** (the spool member **360** is moved along arrow Z**2**). This difference in the pushing force to be applied to the pressure-receiving surface **364** along arrow Z**1** corresponds to the hysteresis error shown in FIG. **23**. There is the hysteresis error, whereby no chattering phenomenon where the spool member **360** is frequently moved along arrow Z**1** and arrow Z**2** while the wiggle back-and-forth movement of the housing **45** along the Y-axis direction is frequently repeated, following a frequent up-and-down fluctuation in the discharge pressure P is generated even when the discharge pressure P of the oil **1** acting on the pressure-receiving surface **364** repeatedly fluctuates up and down at short time intervals. The oil pump **300** according to the third embodiment is configured as described above.

According to the third embodiment, the following effects can be obtained.

More specifically, according to the third embodiment, as hereinabove described, the oil pump **300** includes the spool member **360** linearly moved in the Z-axis direction orthogonal to the Y-axis direction in response to the discharge pressure P of the oil **1** from the discharge port **53**, including the cam-shaped part **362** provided to increase and decrease the eccentricity of the outer rotor **20** with respect to the inner rotor **10** by moving the housing **45** in the Y-axis direction (along arrow Y**1** or arrow Y**2**) following the linear movement along arrow Z**1**. Thus, a change can be easily made by increasing or decreasing the eccentricity of the outer rotor **20** with respect to the inner rotor **10** while moving the housing **45** in the Y-axis direction through the cam-shaped part **362** provided in the spool member **360** following the linear movement of the spool member **360** along arrow Z**1** in response to the discharge pressure P of the oil **1**. Therefore, in the oil pump **300**, only the movement in one direction (along arrow Z**1**) enables an increase and decrease in the eccentricity of the outer rotor **20** with respect to the inner rotor **10**, and hence it is not necessary to switch a position on which the oil pressure acts in response to the discharge pressure P (the rotational speed of the engine **90**) of the oil **1**. Consequently, it is not necessary to provide a hydraulic direction switching valve or the like, and hence the structure of the oil pump **300** can be further simplified.

According to the third embodiment, the housing **45** includes the convex part **48** arranged to face the cam-shaped part **362** of the spool member **360**, and the amount D of protrusion of the cam-shaped part **362** of the spool member **360** with respect to the convex part **48** of the housing **45** changes along the Z-axis direction. Furthermore, the housing **45** is moved in the Y-axis direction (along arrow Y**1** or arrow Y**2**) in response to the change in the amount D of protrusion of the cam-shaped part **362** associated with the movement of the spool member **360** along arrow Z**1** so that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased or decreased. Thus, effectively utilizing a cam mechanism including the cam-shaped part **362** of the spool member **360** and the convex part **48** of the housing **45**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** can be increased or decreased directly following the change in the amount D of protrusion of the cam-shaped part **362** associated with the movement of the spool member **360** along arrow Z**1**.

According to the third embodiment, the cam-shaped part **362** of the spool member **360** includes at least the cam region **71** arranged to face the convex part **48** of the housing **45** when the discharge pressure P of the oil **1** from the discharge port **53** is within the pressure range P**1**, the cam region **72** engaging with the convex part **48** of the housing **45** when the discharge pressure P is within the pressure range P**2** larger than the pressure range P**1**, and the cam region **73** engaging with the convex part **48** of the housing **45** when the discharge pressure P is within the pressure range P**3** larger than the pressure range P**2**. Furthermore, when the spool member **360** is moved along arrow Z**1** so as to sequentially switch the cam-shaped part **362** of the spool member **360** to the cam region **71**, the cam region **72**, and the cam region **73** in response to an increase in the discharge pressure P of the oil **1** from the discharge port **53**, the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** are decreased in the case of the cam region **72**, and the amount of movement of the housing **45** in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** are increased in the case of the cam region **73** from the state where the amount of movement of the housing **45** in the Y-axis direction with respect to the rotation center R of the inner rotor **10** and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** are decreased in the case of the cam region **72**. Thus, based on the cam region **71** corresponding to the case where the discharge pressure P of the oil **1** from the discharge port **53** is within the pressure range P**1**, the cam-shaped part **362** of the spool member **360** is sequentially switched from the cam region **71** to the cam region **72** and from the cam region **72** to the cam region **73** along arrow Z**1** when the discharge pressure P of the oil **1** is increased from the pressure range P**1** to the pressure range P**2** and from the pressure range P**2** to the pressure range P**3**, and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** can be both increased and decreased by the switching from the cam region **71** to the cam region **72** and the switching from the cam region **72** to the cam region **73** following the movement of the spool member **360** along arrow Z**1**. Therefore, desired discharge pressure characteristics can be easily generated in the oil pump **300**.

According to the third embodiment, the cam region **71** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is the eccentricity A**1**, the cam region **72** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is the eccentricity A**2** smaller than the eccentricity A**1**, and the cam region **73** is formed such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction is the eccentricity A**3** larger than the minimum value of the eccentricity A**2**. Thus, based on the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**1**, the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**2** can be adjusted to be smaller than the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**1**, and the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**3** can be adjusted to be larger than the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**2** and smaller than the pump capacity in the case where the discharge pressure P of the oil **1** is within the pressure range P**1**.

According to the third embodiment, the cam region **72** is provided such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is decreased from the eccentricity A**1** to the eccentricity A**2** toward the cam region **73**, and the cam region **73** is provided such that the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is increased from the eccentricity A**2** to the eccentricity A**3** toward the cam region **74**. Thus, when the spool member **360** is moved along arrow Z**1**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction can be easily decreased in the case of the cam region **72**. Furthermore, when the spool member **360** is moved along arrow Z**1**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** associated with the movement of the housing **45** in the Y-axis direction can be easily increased in the case of the cam region **73**.

According to the third embodiment, the cam region **71**, the cam region **72**, and the cam region **73** are continuously provided, and the convex part **48** of the housing **45** is configured to be moved in the Y-axis direction (along arrow Y**1** or arrow Y**2**) by sliding along at least the cam region **72** and the cam region **73** following the movement of the spool member **360**. Thus, the housing **45** can be moved in the Y-axis direction while engaging with the cam-shaped part **362** (the cam region **72** and the cam region **73**) so as to follow the cam shape (inclined shape) of the cam-shaped part **362** when the spool member **360** is moved along arrow Z**1**, and hence based on the cam region **71** corresponding to the case where the discharge pressure P of the oil **1** from the discharge port **53** is within the pressure range P**1**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** can be smoothly decreased in the case of the cam region **72**, and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** can be smoothly increased from the decreased state in the case of the cam region **73**.

According to the third embodiment, the cam region **71** of the spool member **360** is linearly moved to the position corresponding to the convex part **48** of the housing **45** in the pressure range P**1** so that the housing **45** is linearly moved to the first eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**1**, which is the maximum eccentricity. Furthermore, the cam region **72** of the spool member **360** is linearly moved to the position engaging with the convex part **48** of the housing **45** in the pressure range P**2** so that the housing **45** is linearly moved to the second eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**2** smaller than the eccentricity A**1**. Moreover, the cam region **73** of the spool member **360** is linearly moved to the position engaging with the convex part **48** of the housing **45** in the pressure range P**3** so that the housing **45** is linearly moved to the third eccentricity position in the Y-axis direction and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is changed to the eccentricity A**3** larger than the minimum value of the eccentricity A**2**. Thus, the housing **45** can be moved to any of the first eccentricity position, the second eccentricity position, and the third eccentricity position corresponding to the pressure range P**1**, the pressure range P**2**, and the pressure range P**3**, respectively, and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** can be properly adjusted to the eccentricity A**1**, the eccentricity A**2**, and the eccentricity A**3**. Therefore, the oil pump **300** capable of accurately exhibiting the required discharge pressure characteristics can be obtained.

According to the third embodiment, the oil pump **300** includes the spring **305** configured to urge the housing **45** toward the spool member **360** along arrow Y**2**. Thus, when the housing **45** is moved in the Y-axis direction following the linear movement of the spool member **360** along arrow Z**1**, the housing **45** can be moved in the Y-axis direction while properly following the cam shape (concave-convex shape) of the cam-shaped part **362** of the spool member **360** by the urging force of the spring **305** on the housing **45** toward the spool member **360** along arrow Y**2**.

According to the third embodiment, the oil pump **300** includes the spring **306** configured to urge the spool member **360** toward the discharge oil passage **54** (a position on the side of the discharge port **53**) along arrow Z**2**. Thus, when the discharge pressure P of the oil **1** from the discharge port **53** is decreased, the spool member **360** can be easily pushed back along arrow Z**2** by the urging force of the spring **306**, and hence the spool member **360** can perform a reversible operation in response to the discharge pressure P of the oil **1**.

According to the third embodiment, there is the hysteresis error between the characteristics (a shift to the characteristics G**2**, G**3**, and G**4** in FIG. **23**) of the eccentricity of the outer rotor **20** with respect to the inner rotor **10** resulting from the movement of the housing **45** in the Y-axis direction (along arrow Y**1** or arrow Y**2**) in response to the change in the amount D of protrusion of the cam-shaped part **362** generated when the spool member **360** is linearly moved along arrow Z**1** and the characteristics (a shift to the characteristics G**41**, G**31**, and G**21** in FIG. **23**) of the eccentricity of the outer rotor **20** with respect to the inner rotor **10** resulting from the movement of the housing **45** in the direction X in response to the change in the amount D of protrusion of the cam-shaped part **362** generated when the spool member **360** is linearly moved along arrow Z**2**. Thus, even when the discharge pressure P of the oil **1** from the discharge port **53** repeatedly fluctuates up and down at the short time intervals, the characteristics of the eccentricity of the rotation center U of the outer rotor **20** with respect to the inner rotor **10** have the hysteresis error in response to the movement direction of the spool member **360**, and hence generation of the phenomenon (chattering phenomenon) where the linear movement of the spool member **360** along arrow Z**1** and arrow Z**2** following the frequent up-and-down fluctuation of the discharge pressure P and the wiggle back-and-forth movement of the housing **45** in the Y-axis direction based on this are frequently repeated can be avoided in the oil pump **300**. Therefore, even when the discharge pressure P of the oil **1** from the discharge port **53** repeatedly fluctuates up and down at the short time intervals, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** does not vary in a fluctuating manner, and hence the oil **1** can be stably discharged.

According to the third embodiment, the opening **86** that is open to the oil passage part **57** is provided in the pump-housing unit **81** of the pump body **80**. Furthermore, the oil pump **300** is configured such that at least part of the oil **1** suctioned into the suction port **52** through the opening **86** is drawn into the cam-shaped part **362** (cam regions **71** to **75**) of the spool member **360**. Thus, when the housing **45** is moved in the Y-axis direction through the cam-shaped part **362** provided in the spool member **360**, the oil **1**, the pressure of which is decreased to below the discharge pressure P, is easily drawn into the cam-shaped part **362** so that the convex part **48** (the tip end of the convex part **48** coming into contact with the cam-shaped part **362**) of the housing **45** can be smoothly moved, and hence cam operation for moving the housing **45** in the Y-axis direction can be smoothly performed by the spool member **360**. Thus, the smooth discharge pressure characteristics accurately following the discharge pressure P of the oil **1** from the discharge port **53** can be obtained.

Fourth Embodiment

A fourth embodiment is now described with reference to FIGS. **15**, **24**, and **25**. In this fourth embodiment, an example of configuring an oil pump **400** including a spool member **460** including a cam-shaped part **462** different from the spool member **360** (see FIG. **15**) used in the aforementioned third embodiment is described. In the figures, the same reference numerals as those in the aforementioned third embodiment are assigned to and show structures similar to those of the third embodiment.

The oil pump **400** according to the fourth embodiment of the present invention includes the spool member **460**, as shown in FIG. **24**. The spool member **460** is an example of the "cam member" in the present invention.

According to the fourth embodiment, the cam-shaped part **462** of the spool member **460** is formed by connecting a cam region **71**, a cam region **72**, a cam region **473**, and a cam region **475** in this order along a Z-axis direction from a first end (Z1 side) toward a second end (Z2 side). In other words, the cam region **473** is connected to the cam region **475** without providing a cam region **74** (see FIG. **15**) parallel to the Z-axis direction, unlike the spool member **360** (see FIG. **15**). Therefore, the cam region **473** is slightly longer than the cam region **73** (see FIG. **15**) according to the third embodiment, and the cam region **475** extends to the cam region **473** while keeping the same inclination because of no cam region **74** (see FIG. **15**). The cam-shaped part **462** is an example of the "cam region" in the present invention, and the cam region **473** is an example of the "third cam region" in the present invention.

Therefore, the oil pump **400** has characteristics (the discharge pressure characteristics of oil **1** with respect to the rotational speed of an inner rotor **10**) shown in FIG. **25**.

In FIG. **25**, a characteristic G**1** and a characteristic G**2** in the cam region **71** and the cam region **72** associated with the movement of the spool member **460** along arrow Z**1** are the same as in the case of the oil pump **300**. When the rotational speed of an engine **90** (see FIG. **24**) exceeds about 3600 rotations per minute and the discharge pressure P exceeds the maximum value of a pressure range P**2**, a position of the spool member **460** moved along arrow Z**1**, engaging with a convex part **48** is switched from the cam region **72** to the cam region **473**. In the case of the cam region **473**, the eccentricity of an outer rotor **20** with respect to the inner rotor **10** is increased along with a decrease in the amount D of protrusion along arrow Y**1**, and the discharge pressure characteristics are shaped like a characteristic G**6**. When the rotational speed of the engine **90** exceeds about 3900 rotations per minute and the discharge pressure P exceeds the maximum value of a pressure range P3, a position of the spool member **460** moved along arrow Z**1**, engaging with the convex part **48** is switched from the cam region **473** to the cam region **475**. In the case of the cam region **475**, the eccentricity of the outer rotor **20** with respect to the inner rotor **10** is decreased again along with an increase in the amount D of protrusion along arrow Y**1**, and the discharge pressure characteristics are shaped like a characteristic G7. Thus, the oil pump **400** has the discharge pressure characteristics obtained by connecting the characteristics G1, G2, G6, and G7, as shown by a bold solid line.

That the oil pump **400** according to the fourth embodiment also has sections of the characteristic G**2** and the characteristic G**6** between the characteristic G1 and the characteristic G7, as compared with discharge pressure characteristics (characteristics H**1** and H**2**) in an oil pump according to a comparative example means that a pump element **35** (see FIG. **24**) generates no wasted (excessive) oil even at the same rotational speed but the oil pump **400** has characteristics satisfying the pressure of the oil **1** required at a prescribed operation point S3. Therefore, also in the oil pump **400**, no wasted (excessive) oil pressure is generated, and hence pump power is reduced. A reduction in pump power also contributes to a reduction in the load (loss) of the engine **90** and leads to an improved fuel consumption rate. When the rotational speed of the engine **90** (see FIG. **24**) is changed from a high state to a low state, the discharge pressure characteristics are changed in a direction opposite to the above. In other words, the discharge pressure P is changed in the order of the characteristics G7, G6, G2, and G1. The remaining structure of the oil pump **400** according to the fourth embodiment is similar to that of the oil pump **300** according to the aforementioned third embodiment.

According to the fourth embodiment, the following effects can be obtained.

According to the fourth embodiment, as hereinabove described, the oil pump **400** includes the spool member **460** linearly moved in the Z-axis direction orthogonal to a Y-axis direction in response to the discharge pressure P of the oil **1** from the discharge port **53**, including the cam-shaped part **462** provided to increase and decrease the eccentricity of the outer rotor **20** with respect to the inner rotor **10** by moving the housing **45** in the Y-axis direction (along arrow Y**1** or arrow Y**2**) following the linear movement along arrow Z**1**. Thus, a change can be easily made by increasing or decreasing the eccentricity of the outer rotor **20** with respect to the inner rotor **10** while moving the housing **45** in the Y-axis direction through the cam-shaped part **462** provided in the spool member **460** following the linear movement of the spool member **460** along arrow **Z1** in response to the discharge pressure P of the oil **1**. Therefore, unlike the case where the oil pump is provided with a multisystem hydraulic circuit, a hydraulic direction switching valve, etc. and is configured to switch the way of applying oil pressure to the housing **45** (a position of the housing **45** on which oil pressure acts) in response to the discharge pressure P of the oil **1** (the rotational speed of the engine **90**), for example, in the case where the spool member **460** configured to be linearly moved in the Z-axis direction in response to the discharge pressure P of the oil **1** and to increase and decrease the eccentricity of the outer rotor **20** with respect to the inner rotor **10** by moving the housing **45** in the Y-axis direction following the linear movement along arrow **Z1** is provided, the desired discharge pressure characteristics can be generated in the oil pump **400**, similarly to the case where a hydraulic direction switching valve or the like is provided. Thus, the structure of the oil pump **400** can be further simplified. The remaining effects of the fourth embodiment are similar to those of the aforementioned third embodiment.

The embodiments disclosed this time must be considered as illustrative in all points and not restrictive. The range of the present invention is shown not by the above description of the embodiments but by the scope of claims for patent, and all modifications within the meaning and range equivalent to the scope of claims for patent are further included.

For example, while the example of configuring the oil pump **100** (**200**, **300**, **400**) such that the six vanes **30** are arranged between the inner rotor **10** and the outer rotor **20** (**220**) at the equal angular intervals (60-degree intervals) has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. For example, four (90-degree intervals), five (72-degree intervals), eight (45-degree intervals), nine (40-degree intervals) vanes **30**, or the like other than the six vanes **30** may be provided. In this case, the number of outer rotor pieces constituting the outer rotor is changed in response to the number of vanes **30**.

While the example of providing the notch parts **21***f* and **21***g* in each of the outer rotor pieces **21** and allowing the volume parts **62** and **61** to communicate with each other has been shown in each of the aforementioned first, third, and fourth embodiments and the example of providing the notch parts **221***f* and **221***g* in each of the outer rotor pieces **221** and allowing the volume parts **262** and **261** to communicate with each other has been shown in the aforementioned second embodiment, the present invention is not restricted to this. A communicating hole may be provided in each of the outer rotor pieces, for example. As an example, outer rotor pieces **521** may be configured as in a modification shown in FIG. **26**. More specifically, a communicating hole **501** passing through a second engaging piece **21***b* in a thickness direction may be provided in a connection part between a base **21***e* and the second engaging piece **21***b*, and a communicating hole **502** passing through a fourth engaging piece **21***d* in the thickness direction may be provided in an end in which a first engaging piece **21***a* and the fourth engaging piece **21***d* face each other in an axial direction (direction X). The communicating holes **501** and **502** are examples of the "hole" in the present invention.

While the example of using the crankshaft **93** of the internal combustion (engine **90**) as the drive source for the inner rotor **10** has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. For example, an electric motor may be used as the drive source for the oil pump (inner rotor). In this case, the rate of discharge of the oil pump **100** (**200**, **300**, **400**) may be variable in response to the eccentricity of the outer rotor **20** with respect to the inner rotor **10** with the rotational speed of the electric motor kept constant, or in addition to the mechanical pumping of the outer rotor **20** associated with this eccentricity, the rate of discharge of the oil pump **100** (**200**, **300**, **400**) may be more finely adjusted to the required rate of discharge by further changing the rotational speed of the electric motor.

While the example of configuring the oil pump **100** (**200**, **300**, **400**) to be capable of varying the rate of discharge in response to the eccentricity by moving the housing **40** (**45**) parallel to the inner rotor **10**, the rotation center R of which is fixed inside the pump body **50** (**80**), has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. The oil pump may be configured to generate the eccentricity of the outer rotor **20** with respect to the inner rotor **10** by providing a rotational fulcrum on one side of the housing **40** (**45**) and rotating another side of the housing **40** (**45**) by a prescribed angle about this rotational fulcrum, for example.

While the example of shifting the center of the housing **40** with respect to the inner rotor **10**, the rotation center R of which is fixed, has been shown in each of the aforementioned first and second embodiments, the present invention is not restricted to this. More specifically, the oil pump **100** (**200**) may be configured such that the rotation center R of the inner rotor **10** is movable so that the inner rotor **10** is eccentric with respect to the fixed housing **40** and the rate of discharge is variable in response to the eccentricity.

While the example of shifting the center of the housing **45** in the Y-axis direction (along arrow **Y1** or arrow **Y2**) with respect to the inner rotor **10**, the rotation center R of which is fixed, has been shown in each of the aforementioned third and fourth embodiments, the present invention is not restricted to this. More specifically, the oil pump **300** (**400**) may be configured such that the rotation center R of the inner rotor **10** is movable in the Y-axis direction so that the rotation center R of the inner rotor **10** is eccentric with respect to the rotation center U of the fixed housing **45** and the discharge pressure is changed in response to the forward or reverse eccentricity of the inner rotor **10** associated with the movement of the spool member **360** along arrow **Z1**.

While the example of moving the housing **45** forward and reversely in the Y-axis direction in a state where the tip end of the convex part **48** of the housing **45** is brought into contact with the cam-shaped part **362** (**462**) of the spool member **360** (**460**) formed by continuously connecting the multiple cam regions with inclined angles different from each other has been shown in each of the aforementioned third and fourth embodiments, the present invention is not restricted to this. For example, a cam groove having the amount D of protrusion similar to that of the cam-shaped part **362** may be formed in the spool member, an engaging pin fitted into and engaging with this cam groove may be provided in a part of the housing **45** (rotor-housing unit) corresponding to the convex part **48**, and the eccentricity of the outer rotor **20** with respect to the inner rotor **10** may be increased and decreased while the rotor-housing unit is moved in the Y-axis direction (along arrow **Y1** or arrow **Y2**) utilizing engagement between the engaging pin of the rotor-housing unit and the cam groove of the spool member when the spool member **360** is linearly moved along arrow **Z1**.

While the example of configuring the oil pump **300** (**400**) such that the housing **45** (convex part **48**) is pushed along arrow **Y1** by the cam-shaped part **362** (**462**) along with the linear movement of the spool member **360** (**460**) along arrow **Z1** in a state where the convex part **48** of the housing **45** is brought into contact with (engages with) the cam-shaped part **362** (**462**) of the spool member **360** (**460**) along arrow **Y2** by the urging force of the spring **305** has been shown in each of the aforementioned third and fourth embodiments, the present invention is not restricted to this. The oil pump may be configured such that the rotor-housing unit is moved along arrow **Y1** along with the linear movement of the spool member along arrow **Z1** by devising how the spool member engages with the rotor-housing unit (engagement mechanism), for example.

While the example of providing the cam-shaped part **362** including the cam regions **71** to **75** in the spool member **360** has been shown in the aforementioned third embodiment and the example of providing the cam-shaped part **462** including the cam regions **71**, **72**, **473**, and **475** in the spool member **460** has been shown in the aforementioned fourth embodiment, the present invention is not restricted to this. The cam shape (concave-convex shape) of the cam regions may be other than the above. The cam shape of the cam regions can be properly changed in response to an operation point required by a device (motor vehicle or the like) to which oil pressure is supplied.

While the example of providing the spool member **360** (**460**) movable back and forth in the Z-axis direction orthogonal to the Y-axis direction with respect to the housing **45** movable back and forth in the Y-axis direction in the pump body **80** has been shown in each of the aforementioned third and fourth embodiments, the present invention is not restricted to this. The linear movement direction of the spool member **360** in response to the discharge pressure P of the oil **1** is only required to intersect with the movement direction of the housing **45**. For example, the pump body **80** and the internal oil passage (oil pressure path) may be configured such that the spool member **360** is linearly moved along the X-axis direction on which the rotation axis of the inner rotor **10** extends.

While the example of configuring the oil pump **100** (**200**) to rotate the outer rotor **20** (**220**) in the same direction by rotating the inner rotor **10** along arrow **Q2** has been shown in each of the aforementioned first and second embodiments, the present invention is not restricted to this. Similarly to the aforementioned third and fourth embodiments, for example, the oil pump **100** (**200**) may be configured to rotate the inner rotor **10** along arrow **Q1** opposite to arrow **Q2**. More specifically, the vanes **30** are configured to repetitively linearly appear from and disappear into the inner rotor **10** along the radial direction, and hence the rotation direction of the inner rotor **10** is not limited. However, it is necessary to arrange the suction port **52** and the discharge port **53** reversely to the above when the inner rotor **10** is rotated along arrow **Q1**.

While the example of forming each of the outer rotor pieces **221** to have the uniform cross-sectional shape from the end on the X2 side to the end on the X1 side, except for the notch parts **221***f* and **221***g* has been shown in the aforementioned second embodiment, the present invention is not restricted to this. For example, the first engaging piece **221***a* and the second engaging piece **221***b* of each of the outer rotor pieces **221** may be integrally connected to each other in the radial direction in both ends along the direction X. Each of the outer rotor pieces may be configured such that the engagement space **203** is formed in a recess part circumferentially surrounded by the first engaging piece **221***a*, the second engaging piece **221***b*, and side ends connecting the first engaging piece **221***a* and the second engaging piece **221***b* in both ends in the direction X. Therefore, the third engaging piece **221***c* engages with the first engaging piece **221***a* and the second engaging piece **221***b* so as to freely appear from and disappear into the engagement space **203** circumferentially closed. In this case, a communicating hole passing through the second engaging piece **221***b* in the thickness direction may be provided instead of the notch part **221***f* to allow the engagement space **203** and the volume chamber **261** to communicate with each other. According to the structure of this modification, the first engaging piece **221***a* and the second engaging piece **221***b* each having a small thickness (which are thin) are integrally connected to each other in both ends in the direction X, and hence the stiffness of the outer rotor pieces each having the third engaging piece **221***c* that repetitively appears from and disappears into the engagement space **203** can be improved.

While the example of configuring the oil pump **100** (**200**, **300**, **400**) to be capable of varying the rate of discharge in response to the eccentricity by moving the housing **40** parallel to the inner rotor **10**, the rotation center R of which is fixed inside the pump body **50**, has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. For example, the oil pump may be configured to keep the rate of discharge constant in response to the constant eccentricity without the parallel movement of the housing **40**.

While the example in which the outer rotor pieces **21** (**221**) constitute the outer rotor **20** (**220**) made of the aluminum alloy has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. The outer rotor (outer rotor pieces) may be made of a resin material, for example.

While the example of applying the present invention to the oil pump **100** (**200**, **300**, **400**) supplying the oil (lubricating oil) **1** to the internal combustion (engine) has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. The prevent invention may be applied to an oil pump for supplying automatic transmission (AT) fluid (AT oil) to an AT that automatically switches a transmission gear ratio in response to the rotational speed of the internal combustion, for example. Alternatively, the present invention may be applied to an oil pump for supplying lubricating oil to a slide part in a continuously variable transmission (CVT) capable of continuously varying a transmission gear ratio unlike the aforementioned AT (multistage transmission) changing gears by switching a combination of gears. Alternatively, the present invention may be applied to an oil pump for supplying power steering oil to a power steering that drives a steering of a vehicle.

While the example of mounting the oil pump **100** (**200**, **300**, **400**) on a vehicle such as the motor vehicle including the internal combustion (engine) has been shown in each of the aforementioned first to fourth embodiments, the present invention is not restricted to this. The present invention may be applied to an oil pump mounted on an equipment instrument other than the vehicle including the internal combustion (engine), for example. Alternatively, as the internal combustion, a gasoline engine, a diesel engine, a gas engine, etc. are applicable.

DESCRIPTION OF REFERENCE NUMERALS

1 oil
5, **8** engagement space (first engagement space)
6, **7** engagement space (second engagement space)
10 inner rotor
12 vane-housing unit

12*a* recess part (vane-housing unit)
20, **220** outer rotor
21, **221** outer rotor piece
21*a*, **221***a* first engaging piece
21*b*, **221***b* second engaging piece
21*c*, **221***c* third engaging piece
21*d* fourth engaging piece
21*e*, **221***e* base (vane-connecting part)
21*f*, **221***f* notch part (groove part)
21*g*, **221***g* notch part (groove part)
21*h*, **221***h* engaging part (vane-connecting part)
30 vane
31 base (part housed in the vane-housing unit)
32 tip end
35, **235** pump element
40, **45** housing (rotor-housing unit)
46 seat part
47 convex part (cam engaging part)
50, **80** pump body
52 suction port
53 discharge port
54 discharge oil passage
57 oil passage part
58*a* pressure-receiving region
58*b* adjustment region
61, **261** volume chamber (first volume-changing part)
62, **262** volume chamber (second volume-changing part)
63, **263** volume chamber (third volume-changing part)
71 cam region (first cam region)
72 cam region (second cam region)
73, **473** cam region (third cam region)
74 cam region
75, **475** cam region
81 pump-housing unit
85 spring-storing unit
86 opening
90 engine
100, **200**, **300**, **400** oil pump
201, **202** engagement space (first engagement space)
203 engagement space (second engagement space)
305 spring (first urging member)
306 spring (second urging member)
360, **460** spool member (cam member)
361 main body part
362, **462** cam-shaped part (cam region)
363 seat part
364 pressure-receiving surface
365 communicating hole
501, **502** communicating hole (hole)

The invention claimed is:

1. An oil pump comprising:

a rotatable inner rotor that includes a vane-housing unit housing multiple vanes so as to be capable of sliding in a radial direction;

a rotatable annular outer rotor that includes multiple vane-connecting parts connecting tip ends of the multiple vanes on an outside in the radial direction;

first volume-changing parts, which are provided between the inner rotor and the outer rotor, and a first volume of which is changed in response to eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function; and

second volume-changing parts, which are provided in the outer rotor, and a second volume of which is changed by a change in a distance between adjacent vane-connecting parts in a circumferential direction in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function

the second volume-changing parts being configured to be capable of changing the second volume by the change in the distance between the multiple vane-connecting parts of the outer rotor in the circumferential direction by changes in radial slide positions of the tip ends of the vanes on the outside in the radial direction in response to the eccentricity of the inner rotor with respect to the outer rotor,

the outer rotor including multiple outer rotor pieces, each of which is provided for each of the multiple vanes and includes a vane-connecting part,

the multiple outer rotor pieces are circumferentially arranged in a state where adjacent outer rotor pieces engage with each other so as to be capable of changing a distance therebetween in the circumferential direction, and

the adjacent outer rotor pieces engage with each other in the circumferential direction while having engagement spaces constituting the second volume changing-parts, and the second volume of the engagement spaces is changed by a change in the distance between the adjacent outer rotor pieces in the circumferential direction.

2. The oil pump according to claim **1**, further comprising third volume-changing parts, a third volume of which in the vane-housing unit of the inner rotor is changed by slide of the multiple vanes in the radial direction in response to the eccentricity of the inner rotor with respect to the outer rotor, thereby providing a pumping function.

3. The oil pump according to claim **2**, further comprising a suction port that suctions oil and a discharge port that discharges the oil, wherein

in the suction port, the third volume in the vane-housing unit of the inner rotor is gradually increased by gradual slide of the vanes, housed in the vane-housing unit, to the outside in the radial direction, and in the discharge port, the third volume in the vane-housing unit of the inner rotor is gradually decreased by the gradual slide of the vanes, housed in the vane-housing unit, to an inside in the radial direction.

4. The oil pump according to claim **2**, wherein

a thickness of each of parts of the vanes housed in the vane-housing unit is constant.

5. The oil pump according to claim **1**, wherein

grooves or holes that allow the engagement spaces constituting the second volume-changing parts and the first volume-changing parts to communicate with each other are provided.

6. The oil pump according to claim **1**, wherein

the engagement spaces constituting the second volume-changing parts each include a first engagement space located on a first side between two adjacent vanes and a second engagement space located on a second side between the two adjacent vanes.

7. The oil pump according to claim **1**, further comprising a suction port that suctions oil and a discharge port that discharges the oil, wherein

the outer rotor includes multiple outer rotor pieces, each of which is provided for each of the multiple vanes and includes the vane-connecting part, and

in the suction port, the second volume is gradually increased by a gradual increase in the distance between the adjacent outer rotor pieces in the circumferential direction, and in the discharge port, the second volume is gradually decreased by a gradual decrease in the distance between the adjacent outer rotor pieces in the circumferential direction.

8. The oil pump according to claim **1**, further comprising:

a rotor-housing unit that houses the inner rotor and is movable in a first direction so as to change the eccentricity of the inner rotor;

a suction port that suctions oil and a discharge port that discharges the oil; and

a cam member linearly moved in a second direction orthogonal to the first direction in response to discharge pressure of the oil from the discharge port, including a cam region provided to increase and decrease the eccentricity of the inner rotor by moving the rotor-housing unit in the first direction following linear movement in one direction of the second direction.

9. The oil pump according to claim **8**, wherein

the cam member includes a spool member linearly moved in the second direction in response to the discharge pressure of the oil,

the rotor-housing unit includes a cam engaging part arranged to face the cam region of the spool member, and

an amount of protrusion of the cam region of the spool member with respect to the cam engaging part of the rotor-housing unit changes along the second direction, and the rotor-housing unit is moved in the first direction in response to a change in the amount of protrusion of the cam region associated with movement of the spool member in the one direction of the second direction so that the eccentricity of the inner rotor is increased or decreased.

10. The oil pump according to claim **9**, wherein

the cam region of the spool member includes:

a first cam region arranged to face the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a first pressure range,

a second cam region engaging with the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a second pressure range larger than the first pressure range, and

a third cam region engaging with the cam engaging part of the rotor-housing unit when the discharge pressure of the oil from the discharge port is within a third pressure range larger than the second pressure range, and

when the spool member is moved in the one direction of the second direction so as to sequentially switch the cam region of the cam member to the first cam region, the second cam region, and the third cam region in response to an increase in the discharge pressure of the oil from the discharge port, an amount of movement of the rotor-housing unit in the first direction with respect to a rotation center of the inner rotor and the eccentricity of the inner rotor are decreased in a case of the second cam region, and the amount of the movement of the rotor-housing unit in the first direction and the eccentricity of the inner rotor are increased in a case of the third cam region from a state where the amount of the movement of the rotor-housing unit in the first direction with respect to the rotation center of the inner rotor and the eccentricity of the inner rotor are decreased in the case of the second cam region.

11. The oil pump according to claim **10**, wherein

the first cam region is formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is first eccentricity,

the second cam region is formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is second eccentricity smaller than the first eccentricity, and

the third cam region is formed such that the eccentricity of the inner rotor associated with the movement of the rotor-housing unit in the first direction is third eccentricity larger than a minimum value of the second eccentricity.

12. The oil pump according to claim **11**, wherein

the second cam region is provided such that the eccentricity of the inner rotor is decreased from the first eccentricity to the second eccentricity toward the third cam region, and

the third cam region is provided such that the eccentricity of the inner rotor is increased from the second eccentricity to the third eccentricity toward a side opposite to the second cam region.

13. The oil pump according to claim **10**, wherein

the first cam region of the spool member is linearly moved to a position corresponding to the cam engaging part of the rotor-housing unit in the first pressure range so that the rotor-housing unit is linearly moved to a first eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to first eccentricity, which is maximum eccentricity,

the second cam region of the spool member is linearly moved to a position engaging with the cam engaging part of the rotor-housing unit in the second pressure range so that the rotor-housing unit is linearly moved to a second eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to second eccentricity smaller than the first eccentricity, and

the third cam region of the spool member is linearly moved to the position engaging with the cam engaging part of the rotor-housing unit in the third pressure range so that the rotor-housing unit is linearly moved to a third eccentricity position in the first direction and the eccentricity of the inner rotor with respect to the outer rotor is changed to third eccentricity larger than a minimum value of the second eccentricity.

14. The oil pump according to claim **8**, further comprising:

a first urging member that urges the rotor-housing unit toward the cam member; and

a second urging member that urges the cam member toward a position on a side of the discharge port.

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